INTERNATIONAL FOOD
POLICY RESEARCH INSTITUTE
sustainable solutions for ending hunger and poverty

Supported by the CGIAR

IFPRI Discussion Paper 00995

June 2010

Access, Adoption, and Diffusion

Understanding the Long-term Impacts of Improved Vegetable and Fish Technologies in Bangladesh

Neha Kumar

Agnes R. Quisumbing

Poverty, Health, and Nutrition Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI) was established in 1975. IFPRI is one of 15 agricultural research centers that receive principal funding from governments, private foundations, and international and regional organizations, most of which are members of the Consultative Group on International Agricultural Research (CGIAR).

PARTNERS AND CONTRIBUTORS

IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, South Africa, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

AUTHORS

Neha Kumar, International Food Policy Research Institute
Postdoctoral Fellow, Poverty, Health, and Nutrition Division

Agnes R. Quisumbing, International Food Policy Research Institute
Senior Research Fellow, Poverty, Health, and Nutrition Division

Notices

[1] Effective January 2007, the Discussion Paper series within each division and the Director General's Office of IFPRI were merged into one IFPRI–wide Discussion Paper series. The new series begins with number 00689, reflecting the prior publication of 688 discussion papers within the dispersed series. The earlier series are available on IFPRI's website at http://www.ifpri.org/publications/results/taxonomy%3A468.

[2] IFPRI Discussion Papers contain preliminary material and research results. They have been peer reviewed, but have not been subject to a formal external review via IFPRI's Publications Review Committee. They are circulated in order to stimulate discussion and critical comment; any opinions expressed are those of the author(s) and do not necessarily reflect the policies or opinions of IFPRI.

Contents

List of Tables

List of Figures

ABSTRACT

This paper assesses long-term impacts of vegetable and polyculture fish production technologies on a variety of measures of household and individual well-being in Bangladesh. In 1996–1997, households were surveyed in three sites where nongovernmental organizations and extension programs were disseminating agricultural technologies—about two to six years after the technologies were first introduced. The same households were reinterviewed in 2006–2007. Using nearest-neighbor matching to construct a statistical comparison group, we find that long-term impacts differ across agricultural technology interventions and across outcomes. Long-term impacts on household-level consumption expenditures and asset accumulation are, in general, insignificant in the improved vegetables sites, but are positive and significant in the individually operated fishponds sites. Interestingly, impacts on individual nutrient intake, nutrient adequacy, and nutritional status do not necessarily follow the pattern of household-level impacts. The improved vegetable program, despite insignificant or even negative impacts at the household level, seems to have resulted in increases in vitamin A consumption (and iron consumption for men), an increase in average weight-for-age Z-scores among children, and a reduction in the proportion of girls stunted and the proportion of boys underweight. Women in the improved vegetable program also experienced increases in body mass index. Impacts in the group-operated fishponds sites on nutrient intake are mostly negative, although we do find improvements in weight-for-age Z-scores and a decline in stunting and wasting among boys. Although one would expect significant improvements in nutritional status in the individually operated fishponds sites, impacts on nutritional status are mixed. Nutrient availability and the fraction of members consuming the recommended daily allowances have improved significantly for most nutrients considered, among men and women. Although indicators of long-term nutritional status worsen, short-term nutritional status indicators improve. The fraction of women with low hemoglobin levels also decreases significantly. We argue that the differences in long-term and short-term impacts arise from several causes: differences in dissemination and targeting mechanisms that may affect what types of households adopt and benefit from the technologies; initial existing differences between control and treatment groups (controlled for using matching methods); the degree to which a technology is divisible and easily disseminated outside the treatment group; and finally, intrahousehold allocation processes that determine how gains from the new technology are allocated among household members.

Keywords: agricultural technology adoption, long-term impacts, nutrition, Bangladesh

ACKNOWLEDGMENTS

This research was funded by the U.K. Economic and Social Research Council and Department for International Development under their Joint Research Scheme (Award Number RES 167-25-0361). It builds on collaborative work funded by the Chronic Poverty Research Centre, HarvestPlus, and the World Bank. We acknowledge helpful discussions with and comments from Akhter Ahmed, Bob Baulch, Peter Davis, Wahid Quabili, Mohammed Zahidul Hassan, Valerie Mueller, Selim Raihan, and Mohammed Zobair. All errors and omissions are ours.

1. INTRODUCTION

Despite impressive reductions in poverty from the mid-1990s until the onset of the food price crisis in 2007 (BBS 2006; Sen and Hulme 2006), malnutrition continues to be a serious problem in Bangladesh. Child malnutrition rates remain among the highest in the world, and wasting rates rose alarmingly over this decade from 10 to 16 percent (NIPORT/Mitra and Associates/Macro International 2009). Rice-based diets, such as those consumed by the rural poor in Bangladesh, do not provide all the micronutrients necessary for a healthy life (Bouis et al. 1998), and children and women are particularly vulnerable to micronutrient deficiencies because of their relatively higher requirements for growth and reproduction. Moreover, similar to other countries in South Asia (Smith et al. 2003), a pro-male bias in food distribution owing to women's low status and bargaining power within the household may underlie women's inability to meet their micronutrient requirements.

Given the multiple dimensions of poverty and malnutrition in Bangladesh, government and civil society organizations have undertaken many interventions designed to help individuals and households escape poverty and improve their nutritional status, many of them targeted to women. Among them are food-based strategies to alleviate micronutrient malnutrition and interventions that can complement supplementation and fortification programs (Bouis et al. 1998). Promotion of polyculture fish and vegetable production, two foods relatively rich in micronutrients, has been viewed as having the potential to improve micronutrient status in Bangladesh by (1) increasing the supply of micronutrients to the general population and so lowering prices or maintaining constant prices in the face of rising demand due to population and income growth, and (2) directly improving household incomes and intakes of fish and vegetables of producing households. Whereas many evaluations have been conducted to assess the short-term effectiveness of these and similar interventions, relatively little is known about their long-term impact.

This paper assesses the long-term impacts of agricultural technologies introduced more than a decade ago on a variety of measures of household and individual well-being. In 1996–1997, households were surveyed in three sites where nongovernmental organizations (NGOs) and extension programs were disseminating agricultural technologies—about two to six years after the technology was first introduced. The 1996–1997 study examined the effects of the adoption of new vegetable varieties and polyculture fishpond management technologies on household resource allocation, income, and nutrition. The same households were reinterviewed in 2006–2007, between 12 and 16 years after the technologies were introduced, allowing us to capture long-term impacts of the interventions.

Specifically, this paper aims to investigate the following:

- What are the long-term impacts of each of the interventions on household-level outcomes, such as consumption expenditures and asset accumulation?
- Given the interventions' original objective of improving micronutrient consumption, what is the long-term impact of the interventions on food consumption and nutrient intake, particularly micronutrient intake?
- Have the interventions resulted in improvements in nutritional status, particularly of women and children?
- What factors underlie the differential impact of the interventions on the above-mentioned household- and individual-level outcomes?

This study adds to the growing literature that examines the longer-term impacts of interventions on individual and household well-being (Gilligan and Hoddinott 2007; Hoddinott et al. 2008; Maluccio et al. 2009). The panel dataset not only builds on the previous evaluation study but also provides the conditions for a more rigorous evaluation of the impact of these interventions over the long term. First, data on individual, household, and community characteristics at baseline enable us to control for characteristics that affect the probability of a household's participation in the agricultural technology intervention. Second, the timing of the panel survey, 10 years after the original evaluation, permits us to look at long-term impacts of the agricultural technologies, and to control for unobservable time-invariant characteristics using difference-in-differences techniques.[1] Third, we take advantage of the treatment-control design of the original evaluation to undertake three types of comparisons using nearest-neighbor matching, comparing (1) early and late adopters of the technology, and (2) among program members, those with early access to the technology and those waiting to receive the technology. Heckman, Ichimura, and Todd (1997, 1998) and Abadie and Imbens (2002) show that under certain conditions on the data, all of which are satisfied in this study, matching estimators provide reliable estimates of program impact. Finally, we use insights drawn from the qualitative work conducted in 2007 to obtain additional perspectives on the diffusion of agricultural technologies and the potential dilution of their long-term impacts.

Using nearest neighbor matching to construct a statistical comparison group, we find that long-term impacts differ across agricultural technology interventions and across outcomes. The long-term impacts on household-level consumption expenditures and asset accumulation are, in general, insignificant in the improved vegetables site but are positive and significant in the individually operated fishponds sites. The impact on consumption expenditures and assets is negative and significant in the vegetable technologies sites. In terms of nutrient availability at the household level, impacts are insignificant across the three sites. Interestingly, impacts on individual nutrient intake, nutrient adequacy, and nutritional status do not necessarily follow the pattern of household-level impacts. The improved vegetable program, despite insignificant or even negative impacts at the household level, seems to have resulted in increases in vitamin A consumption (and iron consumption for men), an increase in average weight-for-age Z-scores among children, and a reduction in the proportion of girls stunted and the proportion of boys underweight. Women in the improved vegetable program also experienced increases in body mass index (BMI), even though the average calories available to women decreased significantly. Impacts in the group-operated fishponds sites on nutrient intake are mostly negative, although we do see improvements in weight-for-age Z-scores and a decline in stunting and wasting among boys. On average, the height-for-age Z-score decreased significantly among children in these sites and the proportion of girls who are stunted increased. Although one would expect significant improvements in nutritional status in the individually operated fishponds sites, given the large increase in per capita food and total expenditures, impacts on nutritional status are mixed. Nutrient availability and the fraction of members consuming the recommended daily allowances improved significantly for most nutrients considered, among men and women. Although we see a negative impact on height-for-age Z-scores among children and an increase in the proportion of children stunted (driven primarily by girls), the weight-for-age Z-scores did increase, leading to a fall in the proportion of underweight girls. Among adults, the fraction of women with low hemoglobin levels decrease significantly.

The remainder of the paper is organized as follows. Section 2 presents a conceptual framework for evaluating the long-term impact of agricultural technologies, paying attention to processes of adoption, diffusion, and possible dilution of impacts. Section 3 provides an overview of the agricultural technologies, the original sampling design of the 1996–1997 evaluation, a description of the 2006–2007 follow-up, and descriptive statistics for treatment and control groups. Section 4 discusses the methods used in this paper. Section 5 presents results from nearest neighbor matching estimates of program impact, on household-level outcomes, individual nutrient intakes, and individual nutritional status. Section 6 summarizes and concludes.

[1] The previous evaluation, conducted only a few years after the technologies were disseminated, looked only at short-term impacts using single-difference analysis, and relied on with-and-without comparisons arising from the evaluation design without explicitly creating a statistical comparison group. Since the interventions were not randomized, the potential for selection bias contaminating the results still exists. Using panel data does not completely resolve this issue, but it allows us to control for unobserved time-invariant effects.

2. TECHNOLOGY ADOPTION AND THE TIMING OF EVALUATIONS

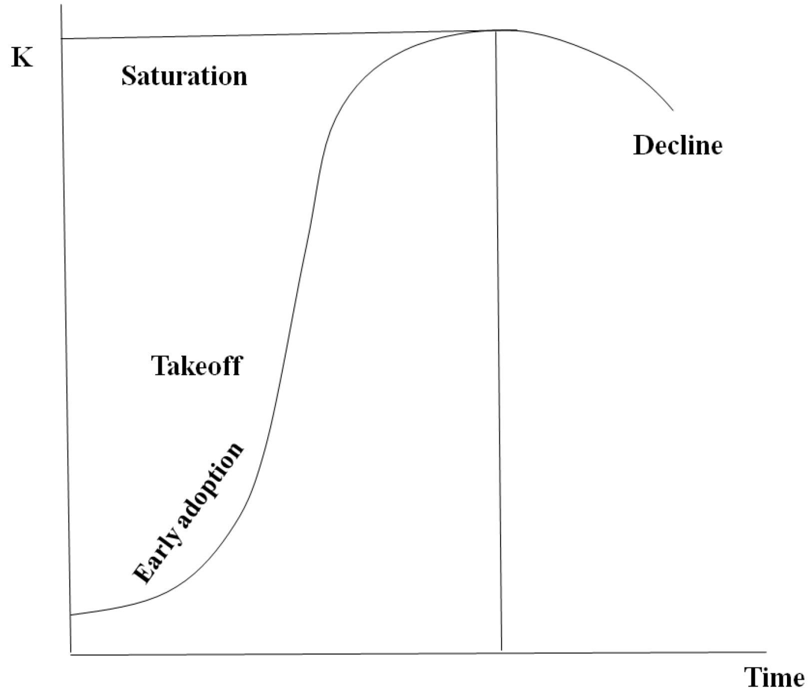
Many antipoverty interventions are evaluated within three to five years of implementation, often because of project implementation cycles. However, short-term measures of program impacts may be misleading. King and Behrman (2008) have argued that the timing of the evaluation—how long after the program is introduced, and the duration of exposure of the target group to the program—is an important but relatively understudied issue in program evaluation. The timing of the evaluation is particularly important for evaluating programs that require changes in the behavior of both service providers and service users—if one evaluates too early, one risks finding only partial or no impact; if one waits too long, one risks losing donor and public support for the program or a scaling up of a badly designed program (King and Behrman 2008, 3).[2] They argue that the duration of exposure to a treatment might vary across program areas and beneficiaries, thus leading to different estimates of program impact, because of three broad reasons. First, organizational factors create leads and lags in program implementation—implementing agencies typically have to roll out a program, service providers have to be trained, and the necessary supplies and equipment have to be in place. Second, spillover effects can arise from learning and adoption by beneficiaries and possible contamination of the control groups. Third, responses to the treatment may be heterogeneous; in the particular case of education- and health-related programs, age and cohort may interact significantly with the duration of the program. In addition, the dissemination and adoption of agricultural technologies also require changes in the behavior of extension agents and farm households, respectively, and leads, lags, and spillover effects are a part of the agricultural technology diffusion process as well. However, evaluating long-term impact must also take into account the nature of the technology (whether *lumpy* or *divisible*) and the nature of the diffusion process itself.

Figure 1 presents a typical S-shaped diffusion curve, characterized by an initial introductory period with a relatively low adoption rate but a high rate of change of adoption (Sunding and Zilberman 2001). During the takeoff period, the innovation (technology) penetrates the potential market, and the marginal rate of diffusion increases. A period of saturation follows, during which diffusion rates are slow, marginal diffusion declines, and diffusion reaches a peak. Finally, for most innovations, a period of decline ensues, during which the innovation is replaced by a new one. Depending on where the technology is on the diffusion curve, the timing of the impact evaluation may lead to vastly different results about the effectiveness of the new technology. Timing issues are particularly important in comparing different types of technologies, which may have different diffusion curves owing to the presence (or absence) of fixed costs, and therefore different patterns of long-term impact, as illustrated by Figure 2.[3] A lumpy technology that involves high fixed costs may have negative short-term returns, relatively limited diffusion throughout the population, and possibly high long-term returns to those that adopted early, as they reap returns to "learning by doing" (upper panel of Figure 2). A more divisible technology may yield higher short-term gains because the technology is easy to adopt, but diffusion and learning from others' experience may lead to later adopters' gaining more than early adopters (bottom panel of Figure 2). Comparing these two programs for which the time path of impact differs, an evaluation undertaken at time *t*1 would indicate that the case in the bottom panel (divisible technology) has a greater impact than the case in the top panel (lumpy technology), whereas an evaluation at time *t*3 would suggest the opposite result.

[2] Although the King and Behrman (2008) paper was written in the context of evaluating social programs, it is also relevant to programs disseminating agricultural technologies.

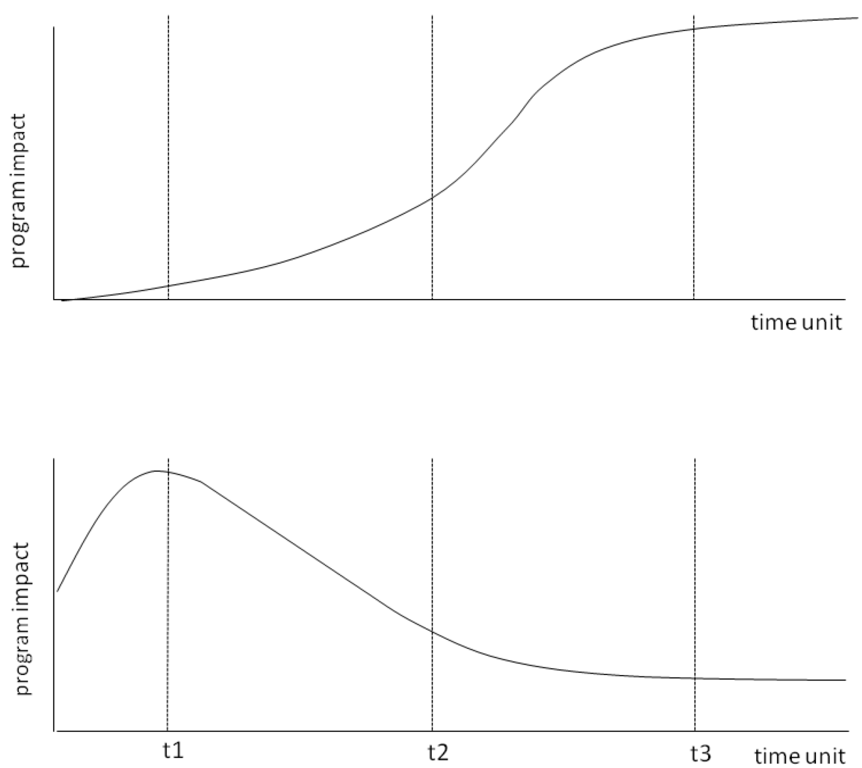
[3] This discussion adapts the exposition of King and Behrman (2008) to the evaluation of two different agricultural technologies.

Figure 1. Diffusion of an agricultural technology over time



Source: Sundling and Zilberman (2001).

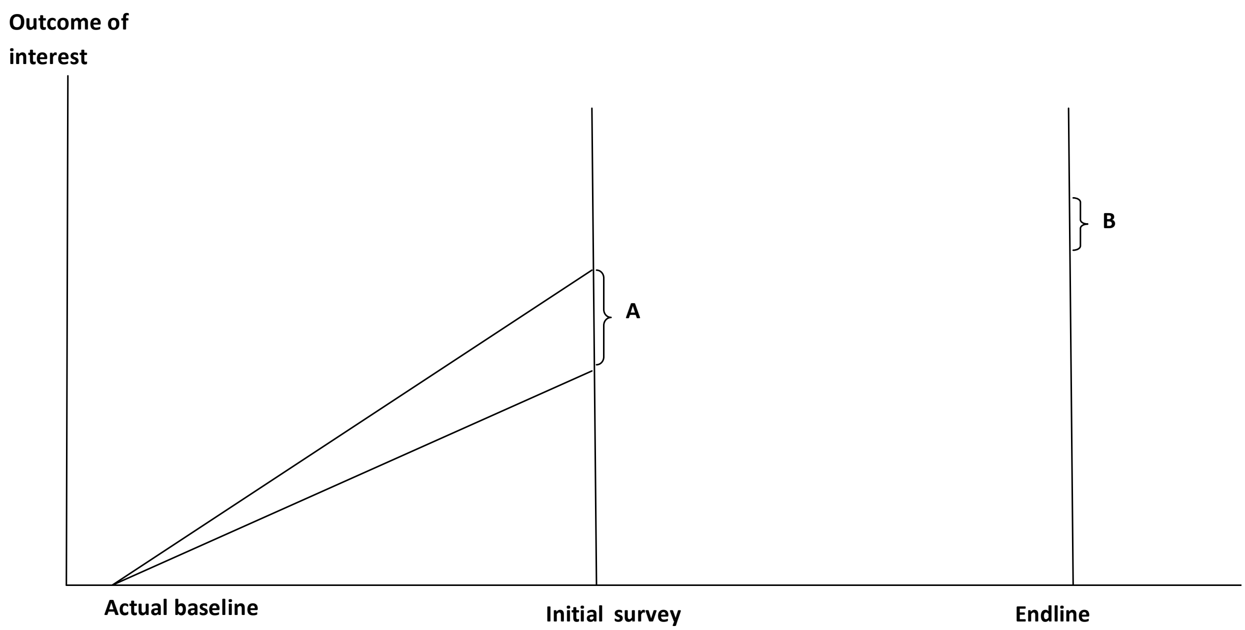
Figure 2. Timing of impact evaluation and impact estimates



Source: King and Behrman (2008).

Yet another complication is introduced by the timing of the initial survey round. In many "real-world" evaluations, the initial round may not correspond to a true baseline, that is, before the introduction of the intervention. If the initial round is conducted after the technology is introduced, and another round is conducted later on, difference-in-differences estimates in impact do not necessarily use absence of the intervention as the reference point. To illustrate, Figure 3 shows the time profile of gains from the adoption of a technology, where we assume that the higher curve is for the treatment group and the lower curve, the comparison group. If the initial survey is collected a few years after the technology was disseminated, the outcome levels among the treatment households already reflect the short-run impact (difference A in Figure 3). The difference in endline outcomes, on the other hand, reflects the long-term impact (difference B in Figure 3), which could be lower than the short-run impact because of the type of intervention (in this case, a technology that is easily transferred). The impact measured by (B - A), or the "difference-in-difference" is therefore the impact over and above the short-term impact, and could be called the "sustained impact" of the intervention.

Figure 3. Short-term and long-term impacts of agricultural technology

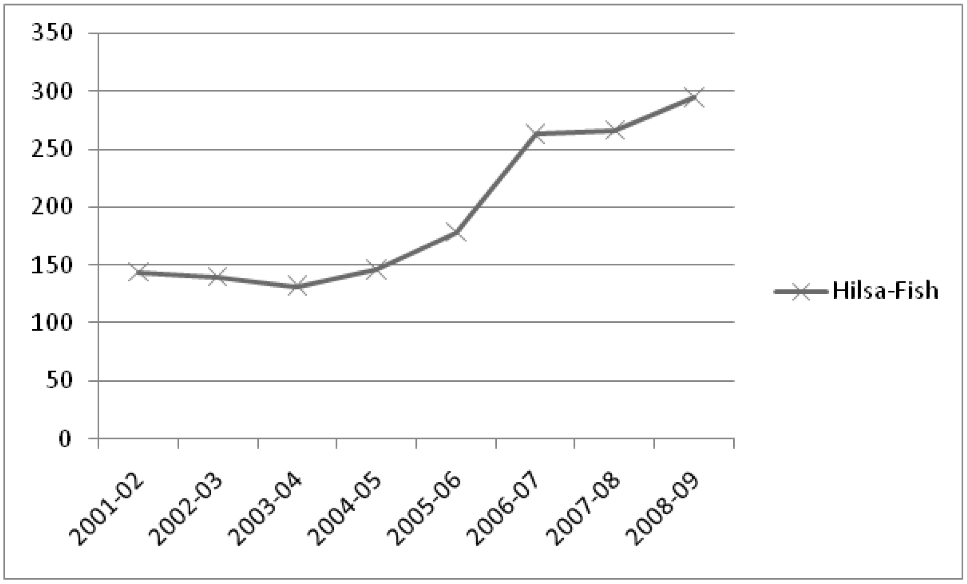


Source: Authors' creation.

Another incentive (or disincentive) of adoption of new varieties is the affect they have on profits. One could argue that adoption of high-yielding varieties may lead to higher supply and thereby reduce the price of the product. The impact on revenue, however, depends on the price elasticity of demand for these products. We will not go into the details of the price elasticity of demand and its impact on profits here, but rather present price trends of selected vegetables and fish for a 9-year period between 2001-2009 in Bangladesh, in Figures 4 and 5, respectively. These figures show that prices of both commodity categories remained more or less stable in the first four to five years (although fish prices are higher in absolute terms) and then started to rise (which may be a reflection of the food price crisis of 2007-08). Given that the prices remained stable for most of the period between the two surveys, it is unlikely that the households' decision to adopt the new technologies is adversely affected by the impact on prices.[4]

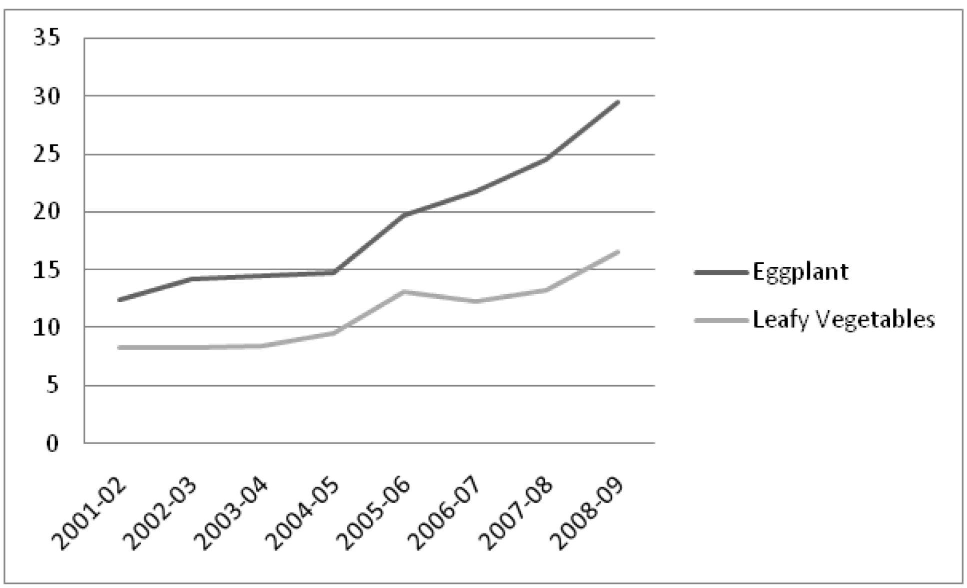
[4] Although the prices presented are national average prices that may not reflect the actual price patterns faced by the households in our sample, vegetables and fish are widely-marketed commodities both in our study sites and nationally, so we do not expect a large divergence between local and national price patterns.

Figure 4. Fish price, 2001-09



Source: Bangladesh Bureau of Statistics.
Note: Prices reported in Bangladeshi taka.

Figure 5. Vegetable prices, 2001-09



Source: Bangladesh Bureau of Statistics.
Note: Prices reported in Bangladeshi taka.

3. DATA AND SAMPLING

An Overview of the Agricultural Technology Interventions

In 1996–1997, the International Food Policy Research Institute and Data Analysis and Technical Assistance Ltd. (DATA) conducted the initial survey for this study to examine the impacts of improved vegetable and polyculture fish management technologies on household resource allocation, income, and nutrition. The initial study also aimed to uncover intrahousehold and gender-differentiated impacts of the new technologies, so data were collected on individuals within households. Households were surveyed in three sites in rural Bangladesh where NGOs and specialized extension programs disseminated new vegetable and fish technologies. The sites were (1) Saturia *thana*, Manikganj district (referred to subsequently as Saturia); (2) Jessore Sadar *thana*, Jessore district (referred to subsequently as Jessore); and (3) Gaffargaon *thana*, Mymensingh district, and Pakundia and Kishoreganj Sadar *thanas*, Kishoreganj district (subsequently referred to collectively as Mymensingh). The agricultural technologies and extension programs at each site are unique, resulting in three case studies that may be compared (see Table 1).[5]

Table 1. Study sites, technologies, and approaches

	Saturia	Jessore	Mymensingh
Community characteristics	Less than two hours northwest of Dhaka; some access to Dhaka markets; high levels of NGO activity; low-lying, flood-prone area	Close to western border with India; less socially conservative but politically volatile	Four to five hours north of Dhaka; remote and socially conservative; not flood prone; some water shortages in dry season
Agricultural technology	Privately grown vegetables on homestead plots	Group-operated polyculture fishponds	Privately-operated polyculture fishponds
Institution originating technology	World Vegetable Center	World Fish Center	World Fish Center
Dissemination approach	Training and credit to all adopters, all of whom are members of women's groups	Training to some members of each adopter group; credit to all group members	Training to all adopters; credit to poor adopters
Type of disseminating institution	Small local NGO	Medium-sized local NGO	Government ministry extension program
Target group	Women NGO members in households with marginal landholdings	Poor women, NGO members, predominantly landless	Individual or joint pond owners

Source: Updated from Hallman, Lewis, and Begum (2007).
Notes: World Vegetable Center was formerly the Asian Vegetable Research and Development Center; World Fish Center was formerly the International Center for Living Aquatic Resource Management; NGO = nongovernmental organization.

Vegetable intervention. The vegetable intervention is an example of a small-scale, divisible technology that can be easily adopted, copied, and disseminated. In Saturia, credit and training in small-scale vegetable growing were introduced by a (then small) local NGO, Gono Kallayan Trust (GKT), to women who grow vegetables on small plots on or near the household compound. These vegetable varieties were initially developed at the World Vegetable Center in Taiwan (formerly the Asian Vegetable Research and Development Center, or AVRDC), adapted to Bangladesh conditions at the Bangladesh Agricultural Research Institute, and introduced by GKT. GKT has been operating in Saturia since 1987, and in March 1994, two years prior to the initial survey, GKT added vegetable production using the

[5] This description draws from Quisumbing and de la Brière (2000), Hallman, Lewis, and Begum (2007), and recent field visits by the authors.

improved seeds to its portfolio of income generation programs.[6] Selected GKT extension agents received training in the new vegetable technologies at AVRDC sites outside Bangladesh. GKT has grown over time into a well-established local NGO, with its own training and conference center, and the improved vegetables are now grown all over Saturia.

Fish intervention. In contrast to the vegetable technology, the polyculture fish technologies have larger entry requirements: ownership or control of a pond, which involves having access to land where the pond is located, and excavation costs. In 1988, the World Fish Center (formerly known as the International Center for Living Aquatic Resource Management, or ICLARM) began providing technical advice to the Fisheries Research Institute (FRI) in Mymensingh in regard to polyculture fish production and other fish culture technologies.[7] Although the basic requirements for polyculture fish cultivation were similar in the Jessore and Mymensingh sites, the implementing agencies used strikingly different modes of dissemination. These agencies also provided different solutions to overcoming the initial barrier to entry—the requirement of owning, or having access to, a pond for cultivation. In Jessore, dissemination took place through a medium-sized local NGO, *Banchte Shekha*. *Banchte Shekha* arranged long-term leases of ponds that are managed by groups of women (ranging in number from 5 to 20) who received credit and training in polyculture fish production methods.[8] *Banchte Shekha* extension agents have received training from both ICLARM and FRI personnel in pond management for polyculture fish production since 1993, so the intervention was three years into implementation when the baseline was conducted. *Banchte Shekha* continues to train women's groups in fish technologies, although groups have begun to graduate from its credit programs and to manage their fishponds without *Banchte Shekha*'s assistance.

In contrast, in Mymensingh, the implementing organization did not attempt to facilitate households' access to ponds. To participate in the program, households had to already own or manage a pond, or share pond ownership with other households. The Mymensingh Aquaculture Extension Program (MAEP) began operating in July 1990 and was jointly implemented through MAEP extension agents and 15 Department of Fisheries extension agents. They provided training to relatively better-off households and training with credit to relatively poorer households, directed at both men and women, but men more often than women. The Danish International Development Agency (DANIDA)–funded MAEP program ended in 2003, and the extension function was absorbed by the Department of Fisheries.[9]

Table 2 shows the extent of adoption of the technologies at the time of the initial survey, based on a census of households. Hallman, Lewis, and Begum (2007) point out that with the exception of the fishpond technologies in Mymensingh, the technologies would have been available to the disseminating institutions in both Saturia and Jessore for only two to three years in each site. Therefore, households in those two sites would have had even shorter experience with the technology at the time of the initial survey. Because the technologies would have been disseminated prior to the initial survey, our initial survey is not a true baseline (in terms of its being fielded prior to the start of the intervention). As is discussed later, we take the timing of the intervention into account when choosing variables with which to create a statistical comparison group.

---

[6] The improved vegetables introduced include tomato, okra, Indian spinach (*pui shak*), red amaranth (*lal shak*), radish, eggplant, amaranth (*data*), kangkong (*kalmi shak*), mung bean, and sweet gourd (Hallman, Lewis, and Begum 2007, 104).

[7] Seven fish species were promoted: silver fish, carp (*katla*), rohu (*rui*), mrigel, mirror carp, *sharputi*, and grass carp. Black fish (*kalibouchi*), shrimp, and tilapia are also cultivated (Hallman, Lewis, and Begum 2007, 106).

[8] Some groups also took advantage of a food-for-work program to excavate joint ponds.

[9] The Mymensingh Aquaculture Extension Program was implemented in three phases between 1989 and 2003. *Phase I* (1989–1993) was a pilot project, with the aim of developing an extension system and spreading the results of DANIDA-supported aquaculture research to pond owners and people with access to ponds, in order to increase the production of fish protein in selected *upazilas* of Mymensingh district. *Phase II* (1993–2000) was intended to increase fish production and was an extension of Phase I programming. It was implemented through a "crash" program in selected *upazilas* of seven districts, including Mymensingh. *Phase III* (2000–2003) was a consolidation phase, which was intended to finalize the approach of partner NGOs and the Department of Fisheries as initiated in Phase II, and to ensure the self-sustaining capacity of aquaculture extension at *upazila* and farmer levels. This phase was extended (at no cost) for an additional year to help ensure a well-planned phase-out and adequate documentation (Orbicon and Lamans 2009).

Table 2. Study sites and extent of adoption

	Saturia	Jessore	Mymensingh
Technology	Vegetables	Group ponds	Private ponds
Adopters as percentage of households in treatment villages (percent)	40	16	50
Year technology introduced	1994	1993	1990
Survey inception year	1996	1996	1996
Elapsed time between introduction of technology and beginning of household survey (years)	2	3	6

Source: Hallman, Lewis, and Begum (2007).

Selection of the initial sample. In each of the three sites, selection of households for the survey was preceded by a census of households in two types of villages: (1) treatment villages, where the disseminating institution had introduced the technology, and (2) comparison villages, where the technology had not yet been introduced but where the disseminating institution had planned eventually to introduce it. In both types of villages, the disseminating institution delivered the same type of supporting service (mainly microfinance). In each site, treatment and comparison households in both village types were affiliated with the same disseminating institution and undertook the same agricultural activities, but those in comparison villages did not have access to the improved technologies. Although the interventions were not randomized across villages, a comparison of village characteristics indicated few significant differences between case and comparison villages in infrastructure and access to services (Bouis et al. 1998); in this paper, we are able to ensure that treatment and comparison groups are statistically comparable, using matching methods (see Section 4).

The household survey then collected data across four different rounds covering a complete agricultural cycle in 1996–1997 for three types of households: (1) adopting households in villages with the technology; (2) likely adopter households (NGO members who expressed interest in adopting the technology) in the villages where the technology was not yet introduced; and (3) a cross-section of all other non-adopting households representative of the general population in the villages under study (non-NGO members plus NGO members not likely to adopt). For households in each of these groups, a four-round survey collected detailed information on production and other income-earning activities by individual family member, expenditures on various food, health, and other items, food and nutrient intakes by individual family member, time allocation patterns, and health and nutritional status by individual family member. See Bouis et al. (1998), Quisumbing and Maluccio (2003), and Hallman, Lewis, and Begum (2007) for more details on information collected during the baseline survey.

The 2006–2007 Follow-Up

In 2006, IFPRI, DATA, and the Chronic Poverty Research Centre (CPRC) began a major study to resurvey the households surveyed in evaluations of three antipoverty interventions, including the agricultural technology study sites. Although the focus of this study was on understanding the drivers and maintainers of chronic poverty in rural Bangladesh, the intervention-comparison groups were maintained from the previous study. In addition, children who had left the original household and set up their own households were tracked as long as they had not migrated from their district. Findings from this integrated qualitative/quantitative study are found in Davis (2007), Quisumbing (2007), and Baulch and Davis (2008).[10]

[10] Phase I involved single-sex focus group discussions to elicit perceptions of changes, their perceptions of the interventions under study, and the degree to which the interventions affected people's lives (compared with other events in the community) (Davis 2007). Phase II was a quantitative survey of the original households and new households that have split off from the original households that have been found in the same district (Quisumbing 2007). Phase III consisted of a qualitative study based on life histories of 140 selected households, focusing on the years between the original survey and the most recent survey

This paper is based on the quantitative survey undertaken in Phase II of the IFPRI/DATA/CPRC study, which took place from November 2006 to March 2007, the same agricultural season as the original survey. The household survey questionnaire was designed to be comparable across sites and also to facilitate comparability with the original questionnaire from the evaluation studies. A community-level questionnaire was administered to key informants at this stage to obtain basic information on each village and changes since the last survey round. In the agricultural technology sites, the survey covered 957 core households that took part in the original survey and 280 "splits" from the original household. Attrition between the baseline and 2006–2007 rounds is relatively low, ranging from 0.4 percent per year in the Saturia and Jessore sites and 1.1 percent per year in the Mymensingh site (Table 3).[11] Although low, the attrition is not random, and it is driven by demographic effects: households with a larger proportion of persons older than age 55 were more likely to leave the sample (Quisumbing 2007). Unobserved locational effects are also clearly important determinants of attrition. Households in Manikganj district were significantly less likely to leave the agricultural technology sample, probably reflecting the ease of interviewing in Manikganj, which is close to Dhaka, and where NGOs have been working for a long time. In contrast, the two *thanas* in the individually operated fishponds sites, which are traditionally more conservative, have much higher attrition rates.

Table 3. Distribution of surveyed households, core households, and split, by intervention site, 2006-2007

	Number of households in 2006-2007 survey round						
		New households due to household division				Attrition	
	Households lost due to migration, absence, death, or merging	Total	Interviewed	Original households reinterviewed	Total number of households in 2007 round	Percent attrited	Percent attrited per year
Saturia: Improved vegetables	13	109	96	313	409	4.0	0.4
Jessore: Group fishponds	15	139	124	324	448	4.4	0.4
Mymensingh: Individual fishponds	40	100	60	320	380	11.1	1.1

Source: IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.

Household Characteristics and Adoption Status

Given the long time interval between the introduction of the technology and the most recent survey, one would expect that the technology, if profitable, would have been more widely adopted, not only by potential adopters but even by those households in the village who may not have been eligible for the program because they were not members of NGOs. Given this long-term view, and because of our interest in implementation modalities, we use alternative definitions of the treatment sample. We first compare households who were early adopters of the technology and those who were late adopters (NGO members who obtained the technology later, as well as households chosen to be representative of the general

(Baulch and Davis 2008).

[11] Our attrition rates compare quite favorably with the longitudinal datasets reviewed in Alderman et al. (2001), where attrition rates range from 6 to 50 percent between two survey rounds and 1.5 to 23.2 percent per year between survey rounds. Although we did not have the resources to track all splits that had migrated to other districts, we obtained names and addresses of migrants from their parents or neighbors. All in all, we were able to track and interview 75 percent of household splits.

population). Second, we assess whether early access to the technology, conditional on program membership, offers long-term benefits to early adopters. Because selection into the program may be endogenous to household characteristics, some of which are unobservable and therefore will not be corrected for using matching methods, a comparison based on program members alone would reduce selection bias arising from unobservables. This second comparison is similar to that in the Bouis et al. (1998) and the Hallman, Lewis, and Begum (2007) studies, which evaluated short-term impacts by comparing adopters and potential adopters among program members.

Table 4 presents household characteristics for early adopters and other households during the initial survey, and per capita consumption expenditures (in 2007 prices) and poverty status in 1996–1997 and 2006–2007. Despite the differences in household characteristics across sites, it is noteworthy that per capita expenditures in all sites have increased in the 10 years between the initial and the 2006–2007 survey rounds, and that the percentage of households below the poverty line (based on the 2005 Bangladesh Bureau of Statistics upper poverty line, adjusted to 2006–2007 prices) has decreased by 4 to 5 percentage points per year. In 1996–1997, households in the individually operated fishponds site (Mymensingh) had larger areas of land owned and higher proportions of household members who have completed both primary and secondary schooling. This did not necessarily translate to higher per capita expenditures or lower initial poverty incidence versus the other sites, although by 2006–2007, both early adopters and other households in the individually operated fishponds sites had higher per capita expenditures, on average, than the other sites.

In 1996–1997, early adopters did not differ significantly from late adopters in Saturia, although some differences in initial characteristics can be discerned in the other two sites. Early adopters in Jessore had significantly lower percentages of female household members between 0 and 4 years of age and higher percentages of males between 15 and 54 years of age. Early-adopter households in Mymensingh had better-educated household heads, higher percentages of males with secondary schooling and females with primary schooling, and significantly larger family sizes. In terms of per capita expenditures, however, the only significant differences are noticeable in Jessore, where early adopters had significantly higher per capita expenditures and lower poverty incidence in 1996–1997 compared with the late-adopting group. Given the differences in initial characteristics between early- and late-adopting groups, particularly in the fishponds sites, controlling for potential differences between these groups that might confound the estimation of program impacts is important.

Table 4. Characteristics of households in agricultural technology study sites, by treatment/control status

	Improved vegetables			Group-operated fishponds			Individually operated fishponds		
	Treatment	Control	Means test (p-value)	Treatment	Control	Means test (p-value)	Treatment	Control	Means test (p-value)
Age of household head	45.41	44.95	0.77	44.72	43.13	0.25	46.22	46.03	0.91
Whether female-headed household	0.04	0.07	0.23	0.07	0.06	0.68	0.00	0.01	0.22
Education of household head (years of schooling)	2.36	2.18	0.69	2.62	2.72	0.81	5.17	4.11	0.04**
Percentage of males with primary schooling	16.24	13.48	0.20	15.49	12.86	0.22	22.17	19.52	0.26
Percentage of males with secondary schooling	2.66	3.47	0.44	3.96	3.03	0.38	10.86	5.78	0.00***
Percentage of females with primary schooling	7.83	5.83	0.16	9.54	8.17	0.38	16.50	10.90	0.00***
Percentage of females with secondary schooling	0.25	0.51	0.43	0.78	0.68	0.85	2.29	1.67	0.41
Area of land owned at baseline (in decimals)	106.71	105.70	0.95	121.92	110.75	0.61	280.54	177.61	0.00***
Household size	5.56	5.51	0.89	5.19	5.22	0.92	6.88	5.59	0.00***
Percent males 0–4 years	4.91	5.20	0.80	3.92	4.14	0.83	5.12	6.12	0.41
Percent females 0–4 years	4.47	5.28	0.50	2.55	5.08	0.02**	4.88	4.66	0.83
Percent males 5–14	13.91	13.24	0.71	12.21	14.09	0.27	13.46	11.52	0.23
Percent females 5–14	12.28	11.03	0.46	11.74	10.97	0.64	11.74	9.96	0.24
Percent males 15–54	29.59	28.74	0.62	30.83	27.86	0.10*	29.72	30.40	0.70
Percent females 15–54	27.31	27.87	0.69	30.30	29.85	0.77	23.19	24.88	0.27
Percent males 55 and over	3.81	3.14	0.44	5.10	4.35	0.49	6.16	6.46	0.81
Percent females 55 and over	3.72	5.50	0.26	3.36	3.67	0.74	5.74	5.99	0.86
Per capita expenditures in Bangladeshi taka and poverty incidence									
Per capita expenditure in baseline survey	962.93	933.20	0.64	1,143.39	919.15	0.00***	978.86	944.12	0.55
Per capita expenditures in 2006–2007	1,409.13	1,546.62	0.14	1,420.34	1,354.96	0.34	1,701.91	1,560.16	0.19
Whether poor in baseline survey	0.68	0.68	0.92	0.42	0.58	0.01***	0.62	0.66	0.48
Whether poor in 2007	0.17	0.13	0.40	0.06	0.11	0.13	0.11	0.18	0.15
Change in poverty incidence	-0.51	-0.54	0.64	-0.37	-0.48	0.07*	-0.53	-0.48	0.45

Source: IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Note: *, **, *** represent significance at 10, 5, and 1 percent, respectively.

4. METHODOLOGY

This paper aims to measure the impact of adopting improved vegetable and fish polyculture technologies on a wide range of household- and individual-level outcomes of those who first received the technologies (see Table 5 for a list of outcomes). This is called the average treatment effect on the treated (ATT). We use the nearest-neighbor matching (NNM) technique proposed by Abadie and Imbens (2002) to estimate the ATT. This method matches comparison households with households that were exposed to the treatment on the basis of observable characteristics. We are interested in estimating the average effect of a binary treatment on a continuous or discrete scalar outcome. For households i, $i = 1, \ldots, N$, let $\{Yi\,(0), Yi\,(1)\}$ denote the two potential outcomes: $Yi(1)$ is the outcome of household i when exposed to the treatment, and $Yi(0)$ is the outcome of household i when not exposed to the treatment. When we estimate the ATT, only one of the two outcomes is observed.

Table 5. Definition of outcomes

Outcome variable	Definition
Household-level expenditures	
Change in adult-equivalent monthly food expenditure, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) in monthly food expenditure (calculated on the basis of a detailed consumption module) adjusted for adult-equivalent units between 1996–2007
Change in adult-equivalent monthly nonfood expenditure, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) in monthly nonfood expenditure (calculated on the basis of a detailed consumption module) adjusted for adult-equivalent units between 1996–2007
Change in adult-equivalent monthly household expenditure, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) in monthly household expenditure (calculated on the basis of a detailed consumption module) adjusted for adult-equivalent units between 1996–2007
Household-level assets	
Change in value of consumer durables, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) of consumer durables owned by the household in 1996–1997 and 2006–2007
Change in value of agricultural durables, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) of agricultural durables owned by the household in 1996–1997 and 2006–2007
Change in value of nonagricultural durables, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) of nonagricultural durables owned by the household in 1996–1997 and 2006–2007
Change in value of jewelry, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) of jewelry owned by the household in 1996–1997 and 2006–2007
Change in value of trees, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) of trees owned by the household in 1996–1997 and 2006–2007
Change in value of land, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) of total land owned by the household in 1996–1997 and 2006–2007
Change in total land area, 1996–1997 and 2006–2007	Percentage change (measured as difference in decimals) of total land area owned by the household in 1996–1997 and 2006–2007
Change in value of livestock, 1996–1997 and 2006-2007	Percentage change (measured as difference in log values) of livestock owned by the household in 1996–1997 and 2006–2007
Change in value of total assets, 1996–1997 and 2006-2007	Percentage change (measured as difference in log values) of total assets owned by the household in 1996–1997 and 2006–2007

Table 5. Continued

Outcome variable	Definition
Household-level incomes	
Change in per capita household income, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) of household income per capita in 1996–1997 and 2006–2007
Change in total household income, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) of total household income in 1996–1997 and 2006–2007
Change in per capita fishpond income, 1996–1997 and 2006–2007	Percentage change (measured as difference in log values) of per capita household income from fishponds in 1996–1997 and 2006–2007
Change in total fishpond income, 1996–1997 and 2006-2007	Percentage change (measured as difference in log values) of household income from fishponds in 1996–1997 and 2006–2007
Change in fraction of income from fish, 1996–1997 and 2006–2007	Percentage change in fraction of total household income from fishponds in 1996–1997 and 2006–2007
Household-level calorie and protein availability	
Change in adult-equivalent calorie availability, 1996-1997 and 2006–2007	Change in total calories available per day adjusted for adult-equivalent units from 1996–2007 constructed from the survey consumption modules on food purchased and consumed in the past 7 days
Change in adult-equivalent protein availability, 2006-2007	Change in total proteins available per day adjusted for adult-equivalent units from 1996–2007 constructed from the survey consumption modules on food purchased and consumed in the past 7 days
Household-level indicators of nutritional status	
Change in percentage of male and female adults (≥ 15 years of age) underweight (BMI < 18.5)	Change in percentage of male and female adults with body mass index < 18.5
Change in percentage of adult females who are anemic	Change in percentage of adult females with hemoglobin levels less than 12 (nonpregnant) or less than 11 (pregnant)
Change in percentage of male and female children stunted (HAZ < -2)	Change in percentage of male and female children with height-for-age Z-score less than -2 from 1996–2007, constructed from the anthropometry data collected in the surveys
Change in percentage of male and female children with ZBMI < -2	Change in percentage of male and female children with body mass index Z-score less than -2 from 1996–2007, constructed from the anthropometry data collected in the surveys
Individual-level indicators of nutritional status	
Change in BMIs of adult males and females, 1996–1997 and 2006–2007	Change in body mass index of males and females ≥ 15 years, 1996–1997 and 2006–2007
Change in hemoglobin levels of adult females	Change in hemoglobin levels of adult females ≥ 15 years, 1996–1997 and 2006–2007
Individual-level indicators of nutrient intake	
Change in individual calorie intake, adult males and females (≥ 15 years), 1996–1997 and 2006–2007	Change in calorie intake per person per day based on 24-hour individual food recall, 1996–1997 and 2006–2007
Change in individual protein intake, adult males and females (≥ 15 years), 1996–1997 and 2006–2007	Change in protein intake per person per day based on 24-hour individual food recall, 1996–1997 and 2006–2007
Change in individual iron intake, adult males and females (≥ 15 years), 1996–1997 and 2006–2007	Change in iron intake per person per day based on 24-hour individual food recall, 1996–1997 and 2006–2007
Change in individual vitamin A (retinol equivalent), adult males and females (≥ 15 years), 1996–1997 and 2006–2007	Change in vitamin A (retinol equivalent) intake per person per day based on 24-hour individual food recall, 1996–1997 and 2006–2007

Source: Authors' estimations.

To estimate the average treatment effect, we estimate the unobserved potential outcome for each observation in the sample. Consider estimating the untreated outcome, $Yi(0)$, for household i with covariates X_i that was exposed to the treatment. If the decision to get the treatment is purely random for households with similar values of the pretreatment variables or covariates, we could use the average outcome of some similar households that were not treated to estimate the untreated outcome. This is the basic idea behind matching estimators proposed by Abadie et al. (2004), which we use here. For each i, matching estimators impute the missing outcome by finding other households in the data whose covariates are similar but that were exposed to the other treatment.

We use NNM to come up with alternative comparison groups, depending on our definition of the treatment. NNM, as previously discussed, allows us to construct a suitable comparison group of households whose outcomes, on average, provide an unbiased estimate of the outcomes that treatment households would have had in the absence of the agricultural technology interventions. Given that adoption of the technology is based on households' satisfying certain targeting criteria related to eligibility for NGO membership and possession of key agricultural assets for adoption (agricultural land for vegetables, fishponds for fish technologies, both of which could be correlated with other factors such as household wealth), simple comparisons of outcomes between treatment and comparison households would yield biased estimates of program impact.

Following Abadie and Imbens (2002), let Y_1 be a household's outcome when it receives an agricultural technology and let Y_0 be that household's outcome otherwise. The impact of technology adoption is the change in the outcome caused by participating in the program: $\Delta = Y_1 - Y_0$. However, for each household, only Y_1 or Y_0 is observed at any given time. Let D be an indicator variable equal to 1 if the household is an adopter and 0 otherwise. The average impact of the treatment on those that receive it—the average impact of the treatment on the treated (ATT)—is defined as

$$ATT = E(\Delta \mid X, D=1) = E(Y_1 - Y_0 \mid X, D=1) = E(Y_1 \mid X, D=1) - E(Y_0 \mid X, D=1),$$

where X is a vector of control variables. However, we are unable to observe outcomes of those households that are otherwise eligible for the program but do not participate, that is, $E(Y_0 \mid X,D = 1)$. In experimental evaluations, households that are eligible for the program ($D = 1$) are randomly selected out for some period of time, providing a reliable estimate of $E(Y_0 \mid X,D = 1)$. However, we know that the agricultural technologies were not randomly allocated in the villages where the disseminating institution is working.

We first begin by estimating a propensity score for being in the treatment group to get a balanced sample of treatment and comparison observations.[12] This involves estimating a probit model that predicts the probability of each household adopting the agricultural technology as a function of observed household, and community, characteristics for treatment and comparison households. The model specification is checked to test (and confirm) equality of the means of these observed characteristics across the treatment and the comparison group samples. Once we have a balanced sample, we use covariate matching that uses a multidimensional metric of distance between values of the observable characteristics to construct the weighted-average difference in outcomes of each treatment household and a weighted average of the outcomes in comparison households. Like propensity score matching, in NNM, control households with propensity scores nearest to the treatment observation receive the highest weight.[13,14] When comparing individuals in program and comparison households, we match using both individual and household characteristics.

Matching methods provide reliable estimates of program impact provided that (1) a comparable group of comparison observations is available, and (2) there is access to carefully collected household

[12] This methods description draws from Gilligan, Hoddinott, and Taffesse (2009).

[13] We use nnmatch in Stata10 to estimate our matching estimators (Abadie et al. 2004).

[14] Note that if the intervention were rolled out at the same time to all NGO members in all the villages in the catchment area, this approach would not be feasible as it would not be possible to construct a statistically robust comparison group. However, considerable evidence exists suggesting that because of resource constraints (mainly due to limited implementation capacity at the initial stages of technology dissemination), program access was rationed.

survey data with many variables that are correlated with technology adoption and the outcome variables (Heckman, Ichimura, and Todd 1997, 1998). As mentioned previously, the initial evaluation survey was designed to include an appropriate comparison group, consisting of members of the same NGO that disseminated the technology in villages where the technology had not yet been disseminated, as well as other households in the same villages who were not members of the NGO. The same survey questionnaire was administered in 1996–1997 and in the 2006–2007 follow-up to adopters, likely adopters, and nonprogram members in the same communities, and includes a large set of variables affecting household welfare and technology adoption. These variables include measures of household head age, age and sex composition of the household, schooling of household members, household size, landholding size, household-level shocks (such as loss of crops or livestock, illness, floods, and so on), and controls for unobserved *upazila*-level effects.

Our approach assumes that after controlling for all observable individual, household, and community characteristics that are correlated with technology adoption and the outcome variable, treatment and comparison households/individuals have the same average outcome as treatment households/individuals would have had if they did not participate in the intervention (defined as adopting the technology early). NNM provides biased estimates of program impact if, for any chosen outcome, it is not feasible to control for enough observable characteristics so that this assumption holds. Drawing both early- and late-adopting households from the same communities helps to reduce the risks of such bias by providing a similar distribution of unobserved community characteristics such as access to markets or local economic shocks. Because we have information on outcome variables from two points in time (1996–1997 and 2006–2007), we estimate the impact as the "difference in differences" (DID) in the outcome between the treatment and comparison group, rather than the "single difference" in outcomes between these two groups as of the initial survey. Earlier analyses using the 1996–1997 data such as Bouis et al. (1998) and Hallman, Lewis, and Begum (2007) were restricted to using single-difference analysis of the initial data; moreover, those studies did not construct a statistical comparison group based on matching methods. DID estimates are known to be less subject to selection bias because they remove the effect of any unobserved time-invariant differences between the treatment and comparison groups.[15]

We also assume that for each treatment household and for all observable characteristics, a comparison group of comparison households with similar propensity scores exists.

[15] We do present single-difference estimates in Table 15 to highlight the difference between short-term and long-term impacts.

5. RESULTS

Adoption of New Technologies by Treatment and Comparison Households

The probit regression used to match households across treatment and comparison groups is presented in Appendix Table A1. Because the initial survey round was undertaken after the technology had been rolled out, we construct the comparison group by matching on characteristics that would not have been affected by the uptake of the technology. Thus, we do not match based on initial asset holdings (which could have been affected by early adoption of the technology) but include areas of owned land (which are less likely to change in the short run), characteristics of the household head, shocks experienced by the household, and age, sex, and educational breakdown of household members.

Because these interventions involve the dissemination and adoption of new agricultural technologies, it is instructive to examine areas devoted to the new technologies in 1996–1997 and in 2006–2007. Tables 6 and 7 present the degree to which each technology was adopted by early and late adopters in 1996–1997 and 2006–2007 in the vegetables and fishponds sites, respectively.[16] Because the 2006–2007 round consisted of a full-year recall, administered only in one round, and the initial round was a four-month recall, data on crop areas across rounds are not strictly comparable. However, comparisons between treatment and comparison groups *within* rounds are comparable, and proportion data, which are standardized by cropped area in a specific round, are comparable. These differences between treatment and comparison households in the extent of adoption of the agricultural technologies need to be taken into account when interpreting the impact estimates.

In 1996–1997, one sees relatively few differences between treatment and comparison households in Saturia in terms of total cropped area under vegetables or total cropped area under improved vegetables (Table 6). Comparison households, however, had significantly larger areas—and larger proportions of cropped area—devoted to high-yielding and local varieties of vegetables. Neither total cropped area under improved vegetables nor the proportion of total area under improved vegetables differed significantly between treatment and comparison households. A decade later, both early- and late-adopting households exhibit similar land allocations to vegetable production, but early adopters have larger areas—and proportions of cropped area—devoted to improved vegetables. About 10 percent of total cropped area is devoted to improved vegetables among early adopters, whereas the late-adopting group allocates only 4 percent of total cropped area to such varieties. Nevertheless, the proportion of crop area devoted to improved vegetables has declined over the past 10 years.

In Jessore, late-adopting households initially cultivated a significantly larger number of improved fish species, although total pond area under cultivation was larger for early-adopting households. The difference between pond area devoted to fish and fish varieties was not significant between early-adopting and late-adopting households (Table 7). By 2006–2007, the difference between early adopters and late adopters had narrowed; both early adopters and comparison households do not significantly differ in terms of number of improved fish species cultivated, pond area under improved fish species, and pond area under fish cultivation. It is only in Mymensingh that early adopters seem to have preserved their lead in terms of the number of improved fish varieties cultivated (Table 7), although early-adopter and late-adopter households do not differ significantly in terms of pond areas under cultivation and under improved species. All in all, this indicates that the improved technologies have diffused well beyond the original treatment villages in the Saturia and Jessore sites.

[16] For brevity, we present these for matched observations of early versus late adopters only. In Hallman, Lewis, and Begum (2007), means are presented for technology-recipient and technology-pending households and villages, based on unmatched observations. By the time of our survey in 2006–2007, the technologies had been disseminated in technology-pending villages.

Table 6. Summary statistics, cropped area by vegetable variety, Saturia

	1996–1997			2006–2007		
Saturia	Treatment	Control	t-stat (absolute)	Treatment	Control	t-stat (absolute)
Total cropped area, in decimals	33.5 (35.82)	42.03 (76.38)	1.27	141.5 (132.53)	141.11 (122.15)	0.02
Total cropped area under high-yielding varieties, in decimals	7.74 (13.34)	21.57 (41.48)	3.97	100.11 (106.67)	96.13 (90.43)	0.33
Total cropped area under local varieties, in decimals	9.25 (17.33)	19.39 (41.37)	2.83	41.39 (48.23)	44.98 (56.76)	0.55
Total cropped area under improved vegetables, in decimals	20.93 (28.44)	23.5 (40.36)	0.65	13.84 (31.94)	8.11 (19.57)	1.91
Fraction of cropped area under high-yielding varieties	0.20 (0.23)	0.39 (0.39)	5.04	0.61 (0.32)	0.67 (0.31)	1.42
Fraction of cropped area under local varieties	0.27 (0.31)	0.60 (0.39)	8.11	0.39 (0.32)	0.33 (0.31)	1.42
Fraction of cropped area under improved vegetables	0.58 (0.31)	0.58 (0.37)	0.14	0.10 (0.16)	0.04 (0.10)	3.52
Number of observations	156	162		110	183	

Source: IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Notes: The t-stat reported is from the test of equality of means; standard deviations are in parentheses.

Table 7. Summary statistics, number of fish species and area cultivated, Jessore and Mymensingh

	1996–1997			**2006–2007**		
	Treatment	**Control**	**t-stat (absolute)**	**Treatment**	**Control**	**t-stat (absolute)**
Jessore						
Total number of improved fish species cultivated	2.71 (2.78)	4.02 (2.44)	3.31	2.32 (1.67)	2.45 (1.78)	0.52
Number of observations	79	95		79	95	
Total pond area under improved fish species, in decimals	365.15 (926.02)	170.65 (417.8)	1.57	45.9 (62.92)	51.36 (78.55)	0.35
Number of observations	40	78		36	63	
Total pond area under fish cultivation, in decimals	402.22 (1,057.73)	184.9 (467.52)	1.55	55.54 (83.58)	50.1 (85.58)	0.33
Number of observations	40	78		40	78	
Mymensingh						
Total number of improved fish species cultivated	6.32 (1.11)	4.97 (1.79)	6.19	4.55 (0.89)	4.01 (1.35)	3.20
Total pond area under improved fish species, in decimals	304.42 (169.61)	262.72 (210.36)	1.48	161.57 (139.79)	139.04 (170.54)	0.97
Total pond area under fish cultivation, in decimals	335.76 (192.28)	303.49 (258.84)	0.96	220.53 (201.99)	189.92 (239.97)	0.94
Number of observations	93	91		93	91	

Source: IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Notes: The t-stat reported is from the test of equality of means; standard deviations are in parentheses.

Impact of Early Adoption

Impacts on consumption, assets, and income. Table 8 presents difference-in-differences NNM estimates of the impact of early adoption on consumption per adult equivalent, asset holdings, per capita income, and fraction of income from fishponds for households in all sites. We find that early adoption of the improved vegetable technologies in Saturia (Table 8, first column) did not have any positive impact on household-level outcomes; indeed, on average, treatment households reduced their food and nonfood consumption relative to comparison households. This is true for value of total assets (-55 percentage points) and in particular value of livestock (-130 percentage points) and land area owned (-0.3 decimals). These results are markedly different from estimates of short-term impact, where we find that consumption expenditures increased by 16 and 14 percentage points for adult-equivalent food and total consumption expenditures, respectively (Table 9), with no significant effects on asset values.

Table 8. Average long-term impact of early adoption on consumption expenditures and asset holdings, all sites (difference-in-differences estimates)

	Saturia		Jessore		Mymensingh	
Outcome variable: Change between 1996–1997 and 2006–2007 in:	ATT	Observations	ATT	Observations	ATT	Observations
Adult-equivalent monthly food expenditure	-0.228** (-2.27)	162	-0.048 (-0.56)	174	0.255*** (3.10)	166
Adult-equivalent monthly nonfood expenditure	-0.142 (-1.46)	162	-0.021 (-0.18)	174	-0.048 (-0.42)	166
Adult-equivalent monthly household expenditure	-0.197** (-2.26)	162	-0.039 (-0.47)	174	0.163* (1.94)	166
Value of consumer durables	-0.186 (-0.74)	162	0.200 (0.91)	174	0.173 (0.98)	166
Value of agricultural durables	0.564 (0.91)	162	-0.711 (-1.02)	174	0.154 (0.26)	166
Value of nonagricultural durables	-0.149 (-0.20)	162	0.096 (0.14)	174	0.349 (0.52)	166
Value of jewelry	-0.747 (-0.98)	162	-0.468 (-0.60)	174	1.186 (1.57)	166
Value of trees	-0.320 (-0.42)	162	0.984 (1.03)	174	-0.603 (-0.70)	166
Value of land	-0.011 (-0.08)	161	-0.680 (-1.21)	174	0.163 (1.31)	166
Area of total land owned	-0.295** (-2.23)	161	-0.082 (-0.47)	174	0.042 (0.37)	166
Value of livestock	-1.309** (-2.28)	162	-1.222** (-2.50)	174	0.391 (0.83)	166
Value of total assets	-0.546** (-2.40)	162	0.161 (0.62)	174	0.322 (1.51)	166
Per capita household income	-0.370* (-1.77)	159	-0.136 (-0.93)	172	-0.009 (-0.07)	166
Per capita fishpond income	-0.081 (-0.40)	162	0.585 (.126)	173	1.756*** (3.78)	166
Fraction of income from fish	-0.009 (-0.29)	162	0.234 (1.16)	174	0.051 (1.49)	165

Source: Authors' computations are from IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Notes: ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively; t-statistics are in parentheses.

Table 9. Average short-term impact of technology adoption on per capita consumption and asset holdings, all sites, 1996-1997 (single-difference estimates)

	Saturia		Jessore		Mymensingh	
Outcome variable	ATT	Observations	ATT	Observations	ATT	Observations
Adult-equivalent monthly food expenditure	0.156** (2.14)	162	0.110 (1.56)	174	-0.230*** (-3.50)	166
Adult-equivalent monthly nonfood expenditure	0.109 (1.11)	162	0.160 (1.34)	174	-0.065 (-0.59)	166
Adult-equivalent monthly household expenditure	0.141* (1.91)	162	0.127 (.167)	174	-0.168** (-2.36)	166
Value of consumer durables	-0.140 (-0.61)	162	0.143 (0.66)	174	-0.131 (-0.82)	166
Value of agricultural durables	-0.695 (-1.30)	162	0.421 (0.63)	174	-0.158 (-0.30)	166
Value of nonagricultural durables	0.517 (0.89)	162	-0.528 (-1.22)	174	-0.278 (-0.61)	166
Value of jewelry	0.132 (0.33)	162	0.334 (0.65)	174	-1.746*** (-2.86)	166
Value of trees	0.953 (1.35)	162	-0.684 (-1.07)	174	0.402 (0.64)	166
Value of land	0.019 (0.09)	162	0.909 (1.34)	174	-0.055 (-0.34)	166
Area of land owned	0.009 (0.05)	162	0.127 (0.44)	174	-0.037 (-0.24)	166
Value of livestock	0.577 (1.27)	162	0.274 (0.96)	174	-0.675* (-1.71)	166
Value of total assets	0.164 (0.83)	162	0.083 (0.30)	174	-0.305 (-1.55)	166
Per capita household income	0.126 (1.43)	162	0.207** (2.35)	173	-0.205** (-2.22)	166
Per capita fishpond income	-0.043 (-0.33)	159	0.228 (0.53)	152	1.378*** (4.26)	141
Fraction of total income from fish	-0.001 (-0.36)	162	-0.077*** (-5.54)	174	-0.003 (-0.11)	166

Source: Authors' computations from IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Notes: ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively; t-statistics are in parentheses.

Very few of the estimated long-term impacts on consumption and asset holdings for Jessore (Table 8, second column) are statistically significant. Comparing early adopters to late adopters, only one effect is statistically significant—the negative and large change in value of livestock (113 percentage points). Similar to the case of Saturia, the short-run results for Jessore (Table 9, second column) are also quite different from the long-term impact. In the short run, early-adopting households in Jessore experienced an increase of about 21 percentage points in per capita household income and an 8 percentage point decline in the fraction of income from fishponds. However, our difference-in-differences results indicate that those gains were not sustained over the long term.

In contrast to the other two sites, early adoption of the polyculture fish technology seems to have paid off in Mymensingh, where early adopters experienced substantial increases in consumption expenditure (per adult equivalent) and asset holdings (Table 8, third column). Food consumption and total consumption per adult equivalent increased by 25 percentage points and 16 percentage points, respectively, among early-adopting households. Results for income corroborate the impact estimates for consumption. We find an increase of almost 175 percentage points in per capita income from fishponds for the treated households. These positive long-term impacts are markedly different from the short-term impacts (Table 9, third column). In the short run, as early adopters shouldered the up-front costs of adopting the technology, they decreased their consumption expenditures and asset holdings relative to comparable late-adopting households. However, whereas per capita incomes declined in the short run, early adopters did experience significant increases in per capita fishpond incomes.

Impacts on household nutrient availability and individual nutrient intake. We also examine the impact of early adoption on nutrient availability and intake in the three intervention sites (Table 10). We use two sources of nutrient availability and intake data. Total calorie and protein *availability* was computed by converting quantities reported in the food consumption module to their nutrient equivalents using conversion factors from Helen Keller International. Those estimates of availability are at the household level and are adjusted using adult-equivalent units. Nutrient *intake* data were computed using 24-hour individual food recall surveys administered in 1996–1997 and 2006–2007; weights of food consumed were converted to nutrient equivalents using the International Minilist conversion table. The intake data enable us to examine differential impacts of early adoption on the nutrient intake of individuals within the household. Thus, the household-level outcomes are the change in adult-equivalent calorie availability, whereas the individual outcomes are the change in total calories, total protein, total iron, and total vitamin A consumed by children and by adults (disaggregated by sex). Using the individual intake data, we also compute the change in the fraction of family members (adults, by gender) whose daily nutrient consumption falls short of the recommended daily allowance (RDA). Because the household-level availability figures were derived from a food consumption module, and the intake data from a 24-hour recall survey, we do not expect aggregates to be identical.

We find that whereas the early adoption of improved vegetables did not increase household calorie availability per adult equivalent (Table 10, first column), it significantly increased iron and vitamin A consumption by both men and women. Even though women consume significantly fewer calories and their protein intake has gone down, vitamin A consumption by women increased. Interestingly, qualitative work in the vegetables site had previously found that women tended to increase their consumption of the improved vegetables, which are rich sources of vitamin A (Naved 2000), partly because such vegetables are considered “low status” and are therefore not consumed by men. Ten years later, it appears that both men and women have increased their consumption of vitamin A, with women’s consumption increasing slightly more than men’s.

In Jessore, where fish technologies were disseminated through group-operated fishponds, protein consumption by men declined, and the fraction of household members consuming less than the RDA for calories and protein similarly increased (Table 10, second column). The fraction of men consuming less than the calorie RDA also increased, and the fraction of women consuming less than the RDA of calories and iron increased significantly.

Finally, in Mymensingh, reflecting the overall increase in food expenditures, calorie availability and consumption improved significantly (Table 10, third column). Total protein, iron, and vitamin A consumption of men increased, and consumption of calories, protein, and vitamin A by women also increased. Hand in hand with increased consumption, there was a significant decline (almost 15 percentage points) in the fraction of members consuming less than the RDA of calories, which seems to be driven primarily by a fall in the fraction of women who consume less than the RDA of calories. The proportion of women consuming less than the iron RDA also decreased. There is also some evidence that the fraction of household members consuming less than the RDA of protein has gone down. Interestingly, however, children did not experience significant increases in nutrient consumption at any of the sites.

Table 10. Average impact of early adoption on nutrient availability and intake, household and individual outcomes, all sites (difference-in-differences estimates)

Outcome variable: Change between 1996–1997 and 2006–2007 in:	Saturia		Jessore		Mymensingh	
	ATT	Observations	ATT	Observations	ATT	Observations
Per adult equivalent calorie availability	-135.7 (-0.40)	148	-220.5 (-0.59)	158	954.7 (3.04)	149
Total calorie consumption by children	-170.69 (-.123)	109	-134.21 (-1.01)	95	49.44 (0.37)	132
Total protein consumption by children	0.81 (0.19)	125	-2.47 (-0.75)	95	0.95 (0.23)	132
Total iron consumption by children	0.86 (1.30)	109	-0.62 (-0.96)	95	0.23 (0.21)	132
Total vitamin A consumption by children	-31.70 (-0.32)	109	-172.51 (-1.37)	95	19.98 (0.19)	132
Total calorie consumption by men	-65.59 (-0.47)	299	-104.03 (-0.90)	293	63.46 (0.48)	300
Total protein consumption by men	4.10 (1.23)	299	-7.04** (-2.05)	293	8.77** (2.29)	300
Total iron consumption by men	2.12*** (2.88)	299	-0.68 (-0.76)	293	2.19** (2.37)	300
Total vitamin A consumption by men	207.40** (2.04)	299	-150.48 (-1.36)	293	216.97** (2.09)	300
Total calorie consumption by women	-451.41*** (-3.82)	278	40.17 (0.55)	297	184.21* (1.73)	282
Total protein consumption by women	-7.14*** (-2.69)	302	1.19 (0.61)	297	7.83** (2.19)	282
Total iron consumption by women	-0.11 (-0.13)	278	0.87 (1.53)	297	1.06 (1.03)	282
Total vitamin A consumption by women	256.63** (2.10)	278	52.86 (0.49)	297	157.69* (1.89)	282
Fraction of household members consuming less than RDA calories	-0.016 (-0.24)	162	0.176*** (2.60)	174	-0.149** (-2.34)	166
Fraction of household members consuming less than RDA protein	-0.048 (-0.74)	162	0.146* (1.71)	174	-0.168** (-2.43)	166
Fraction of household members consuming less than RDA iron	-0.030 (-0.66)	162	0.010 (0.17)	174	-0.002 (-0.04)	166
Fraction of household members consuming less than RDA vitamin A	-0.114 (-1.31)	162	0.043 (0.41)	174	-0.194** (-2.14)	166
Fraction of adult male members consuming less than RDA calories	-0.127 (-1.10)	141	0.271** (2.47)	158	-0.127 (-1.35)	143
Fraction of adult male members consuming less than RDA protein	-0.052 (-0.46)	141	0.097 (0.74)	158	-0.270*** (-3.18)	143
Fraction of adult male members consuming less than RDA iron	-0.042 (-0.79)	141	-0.075 (-0.82)	158	-0.081* (-1.85)	143
Fraction of adult male members consuming less than RDA vitamin A	-0.135 (-1.15)	141	0.016 (0.13)	158	-0.178 (-1.56)	143
Fraction of adult female members consuming less than RDA calories	0.146 (1.35)	155	0.204** (2.10)	171	-0.272** (-2.50)	158
Fraction of adult female members consuming less than RDA iron	0.122 (1.19)	155	0.199** (2.03)	171	-0.228** (-2.31)	158
Fraction of adult female members consuming less than RDA vitamin A	0.002 (0.05)	155	-0.036 (-0.72)	171	0.032 (0.43)	158
Fraction of adult female members consuming less than RDA protein	-0.109 (-1.18)	155	-0.012 (-0.10)	171	-0.223** (-2.02)	158

Source: Authors' computations from IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Notes: ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively; t-statistics are in parentheses; RDA = recommended daily allowance.

Impacts on individual nutritional status. How do the changes in nutrient availability and intake translate to changes in nutritional status? Such impacts will be mediated by a host of other factors, including level of activity (work effort), underlying health conditions (illness), and, for women, pregnancy and lactation status. Table 11 presents estimates of impacts on such individual-level outcomes as change in the height-for-age Z-score (HAZ) and the body mass index Z-score (ZBMI) for children; change in body mass index (BMI) for adult men and women; and change in hemoglobin levels for women, presented at both the individual and household levels. The individual analyses are conducted for individuals who were in the household both at baseline and follow-up, and thus sample sizes are much smaller (and have less power) in comparison with the household-level analyses. At the household level, we examine the fraction of children/boys/girls who are stunted (HAZ less than -2), the fraction of children/boys/girls who are thin (ZBMI less than -2), the fraction of men/women with low BMI (defined as less than 18.5), and the fraction of women with anemia (hemoglobin defined as less than 12 grams/deciliter and less than 11 grams/deciliter for pregnant or lactating women).

Table 11. Average impact of early adoption on nutritional status of children and adults, all sites (difference-in-differences estimates)

	Saturia		Jessore		Mymensingh	
Outcome variable: Change between 1996–1997 and 2006–2007 in:	ATT	Observations	ATT	Observations	ATT	Observations
Individual-level outcomes						
HAZ for children	0.418	46	-2.86***	41	-0.963***	34
	(1.51)		(-7.89)		(-4.25)	
ZBMI for children	0.460*	47	3.02***	41	1.742***	34
	(1.90)		(7.18)		(3.80)	
BMI for men	-0.391*	280	-0.099	275	-0.181	224
	(-1.78)		(-0.39)		(-0.74)	
BMI for women	0.539*	186	0.368	153	-0.504	163
	(1.91)		(1.03)		(-1.40)	
Hemoglobin for women	0.035	129	0.235	112	0.01	109
	(0.14)		(0.49)		(0.03)	
Household-level outcomes						
Fraction of children with HAZ < -2	-0.045	111	-0.134	114	0.265**	107
	(-0.41)		(-1.21)		(2.53)	
Fraction of boys with HAZ < -2	-0.284	54	-0.411**	54	-0.146	70
	(-1.55)		(-2.17)		(-0.98)	
Fraction of girls with HAZ < -2	-0.284*	57	0.438**	58	0.293*	61
	(-1.88)		(2.31)		(1.82)	
Fraction of children with ZBMI < -2	0.034	111	-0.027	114	0.088	107
	(0.30)		(-0.24)		(1.00)	
Fraction of boys with ZBMI < -2	-0.432***	54	-0.621***	54	-0.220	70
	(-2.61)		(-2.78)		(-1.46)	
Fraction of girls with ZBMI < -2	-0.108	57	-0.069	58	-0.563***	61
	(-0.70)		(-0.43)		(-5.72)	
Fraction of men with low BMI	0.086	128	-0.048	138	-0.060	115
	(0.99)		(-0.50)		(-0.77)	
Fraction of women with low BMI	0.004	157	-0.061	165	-0.085	146
	(0.04)		(-0.74)		(-0.89)	
Fraction of women with low hemoglobin	0.002	118	-0.082	122	-0.295**	95
	(0.02)		(-0.69)		(-2.05)	

Source: Authors' computations from IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Notes: HAZ = height-for-age Z-score; ZBMI = body mass index Z-score; BMI = body mass index. ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively; t-statistics are in parentheses.

By and large, early adoption had beneficial nutritional impacts in Saturia (Table 11, first column). At the individual level, ZBMIs for children and BMIs for women increased significantly, although BMIs for men decreased. At the household level, the proportion of stunted girls (with HAZ < -2) and the proportion of thin boys (ZBMI < -2) decreased. It is possible that the targeting modality—working through women's groups that emphasize women's empowerment, and disseminating vitamin A and iron-rich vegetables that are consumed by women—may have had a positive net impact on the nutritional status of women and children (especially girls), despite the insignificant impacts on household-level outcomes.

In Jessore (Table 11, second column), we find mixed impacts on the long-term nutritional status among children. The HAZ for children decreased, which is possibly driven by an increase in the fraction of stunted girls that is larger than the decline in the fraction of stunted boys. The ZBMI among children, on the other hand, increased, and the fraction of thin boys dropped by 62 percentage points. There are no significant impacts of early adoption on men's or women's nutritional status. In spite of the positive impacts on consumption expenditures and calorie availability at the household level, children of early adopters in Mymensingh (Table 11, third column) did not experience long-term nutritional improvements. Relative to late adopters, HAZs of children decreased, and the fraction of thin children increased. However, we do observe an improvement in the ZBMI and the fraction of underweight girls. And, in contrast to Saturia, where women's nutritional indicators improved, despite low income or consumption gains, BMIs for women in Mymensingh were not significantly affected. Given the previous results showing that the percentage of women with calorie deficiency declined, it is possible that women's increased work effort was not compensated for by the increase in nutrient intake. However, the reduction in the fraction of women consuming less than the RDA of iron does translate into a lower fraction of women with low hemoglobin status in Mymensingh.

Impact of Early Access, Conditional on Program Membership

It could be argued that our estimated impacts of adopting the technology could be contaminated by underlying unobservable differences between program members and nonmembers, and that controlling for observables using matching methods may not completely eliminate that bias. If we assume that program members are more similar to each other than nonmembers, we could conduct the comparison of early adopters (technology adopting) and late adopters (technology pending) among program members only, and thus avoid confounding the estimates with unobserved selectivity bias. This is similar to the comparison conducted by Bouis et al. (1998) and Hallman, Lewis, and Begum (2007), although they did not use matching methods.

In the long run, did NGO members with earlier access to the technology benefit more from the technology than those NGO members who received the technology later? Unlike the short-term results of Hallman, Lewis, and Begum (2007), we do not find that earlier access to the vegetable technology by NGO members in Saturia yields long-term gains in terms of consumption expenditures (Table 12, first column). Although early adopters have higher values of agricultural durables, the values of other assets, such as nonagricultural durables, trees, livestock, and land area, are lower. Early-adopting NGO members appear to have lower per adult equivalent calorie availability, lower calorie consumption by children, men, and women, and lower protein consumption by women (Table 13, first column). Men's iron and vitamin A consumption has increased, however, and the fraction of men consuming less than the RDA for iron has declined, while the fraction of men consuming less than the RDA of calories has gone up. Among NGO members who had early access to the technology, impacts on nutritional status are mixed, although nutritional improvements tend to favor children, especially girls, who typically have worse nutritional status than boys in this country context (Table 13, first column). Children experienced improvements in both long-term and short-term nutritional status, as indicated by an increase in the HAZs and ZBMIs. The fraction of stunted girls also declined significantly. Among adults the impacts were largely negative—men's BMI decreased and the fraction of women with low hemoglobin increased.

Table 12. Impact of early access on consumption expenditures and asset holdings given program membership, all sites (difference-in-differences estimates)

	Saturia		Jessore		Mymensingh	
Outcome variable: Change between 1996–1997 and 2006–2007 in:	ATT	Obser-vations	ATT	Obser-vations	ATT	Obser-vations
Adult-equivalent monthly food expenditure	-0.153 (-1.20)	86	0.462*** (3.98)	81	0.041 (0.40)	111
Adult-equivalent monthly nonfood expenditure	0.006 (0.04)	86	0.114 (0.65)	81	-0.401 (-2.43)	111
Adult-equivalent monthly household expenditure	-0.109 (-0.94)	86	0.376*** (3.29)	81	-0.106 (-0.97)	111
Value of consumer durables	-0.128 (-0.40)	87	0.629** (2.37)	81	0.053 (0.24)	111
Value of agricultural durables	2.769*** (3.59)	87	1.298 (1.16)	81	0.141 (0.19)	111
Value of nonagricultural durables	-1.841* (-1.87)	87	-4.238*** (-3.88)	81	-0.437 (-0.56)	111
Value of jewelry	-1.922 (-1.54)	87	3.040*** (3.22)	81	0.340 (0.35)	111
Value of trees	-3.293** (-2.39)	87	6.300*** (5.11)	81	-0.655 (-0.55)	111
Value of land	-0.279* (-1.73)	87	-1.510*** (-3.27)	81	0.033 (0.23)	111
Area of total land owned	-0.668*** (-4.81)	87	-0.198 (-1.34)	81	-0.022 (-0.19)	111
Value of livestock	-3.131*** (-4.34)	87	-2.334*** (-4.77)	81	0.288 (0.52)	111
Value of total assets	0.174 (0.71)	87	0.458 (1.17)	81	-0.101 (-0.39)	111
Per capita household income	-0.264 (-1.30)	86	-1.309*** (-7.31)	80	0.052 (0.32)	111
Per capita fishpond income	-0.843 (-4.21)	87	-1.135* (-1.87)	81	0.418 (0.82)	111
Fraction of income from fish	0.002 (1.59)	87	1.688*** (3.16)	81	0.028 (0.61)	111

Source: Authors' computations from IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Notes: ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively; t-statistics are in parentheses.

Table 13. Impact of early access on nutrient consumption given program membership, all sites (difference-in-differences estimates)

Outcome variable: Change between 1996–1997 and 2006–2007 in:	Saturia		Jessore		Mymensingh	
	ATT	Observations	ATT	Observations	ATT	Observations
Per adult equivalent calorie availability	-1,014.03 (-2.35)	76	165.106 (0.33)	74	622.07 (1.51)	102
Total calorie consumption by children	-358.50** (-2.08)	80	-252.04 (-1.40)	48	86.68 (0.58)	73
Total protein consumption by children	-0.40 (-0.08)	85	-6.92 (-1.37)	48	3.72 (0.91)	73
Total iron consumption by children	0.51 (0.58)	80	-0.51 (-0.66)	48	1.42 (1.28)	73
Total vitamin A consumption by children	15.16 (0.15)	80	-3.76 (-0.02)	48	235.77 (1.29)	73
Total calorie consumption by men	-314.40* (-1.80)	211	-269.40* (-1.85)	200	127.76 (0.95)	221
Total protein consumption by men	1.53 (0.35)	211	-8.41** (-2.00)	200	10.50** (2.69)	221
Total iron consumption by men	2.85*** (2.89)	211	-1.34 (-1.16)	200	2.60*** (2.65)	221
Total vitamin A consumption by men	303.80*** (2.84)	211	-20.59 (-0.16)	200	287.31** (2.36)	221
Total calorie consumption by women	-586.62*** (-4.77)	200	14.68 (0.15)	191	215.05* (1.76)	199
Total protein consumption by women	-9.29*** (-2.78)	205	3.36 (1.32)	191	10.15** (2.55)	199
Total iron consumption by women	-0.39 (-0.43)	200	1.51** (2.05)	191	1.67 (1.46)	199
Total vitamin A consumption by women	196.31 (1.45)	200	114.63 (0.89)	191	437.26*** (3.65)	199
Fraction of household members consuming less than RDA calories	0.168 (1.49)	87	0.367*** (3.64)	81	-0.123 (-1.32)	111
Fraction of household members consuming less than RDA protein	0.071 (0.87)	87	0.391*** (2.98)	81	-0.201** (-2.32)	111
Fraction of household members consuming less than RDA iron	-0.019 (-0.23)	87	0.158 (1.38)	81	0.016 (0.23)	111
Fraction of household members consuming less than RDA vitamin A	0.145 (1.11)	87	-0.146 (-1.06)	81	-0.013 (-0.13)	111
Fraction of adult male members consuming less than RDA calories	0.083 (0.48)	79	0.013 (0.07)	74	0.008 (0.07)	98
Fraction of adult male members consuming less than RDA protein	0.609*** (3.82)	79	-0.443** (-2.22)	74	-0.160 (-1.40)	98
Fraction of adult male members consuming less than RDA iron	-0.198*** (-3.13)	79	-0.609*** (-4.13)	74	-0.046 (-0.85)	98
Fraction of adult male members consuming less than RDA vitamin A	-0.190 (-1.14)	79	-0.115 (-0.71)	74	0.049 (0.37)	98
Fraction of adult female members consuming less than RDA calories	0.096 (0.60)	82	0.886*** (6.14)	80	-0.146 (-1.26)	105
Fraction of adult female members consuming less than RDA iron	0.211 (1.36)	82	0.921*** (5.91)	80	-0.083 (-0.71)	105
Fraction of adult female members consuming less than RDA vitamin A	1.164*** (2.99)	82	0.211** (2.17)	80	0.118 (1.34)	105
Fraction of adult female members consuming less than RDA protein	-0.503*** (-3.34)	82	-0.303* (-1.82)	80	-0.067 (-0.55)	105

Source: Authors' computations from IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Notes: ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively; t-statistics are in parentheses; RDA = recommended daily allowance.

In Jessore, there are indications that, among NGO members, having early access to the technology led to decreases in per capita household income and per capita fishpond income (even if the fraction of income from fish was higher) and the value of nonagricultural durables, land, and livestock (Table 12, second column). Among NGO members, however, there were some benefits to having earlier access to the technology. They had significantly larger per adult equivalent food and total consumption expenditures and the value of jewelry and trees went up faster for them than the NGO members without access to the technology. Women in households where NGO members had earlier access to the technology increased iron consumption over the long run relative to late-adopting NGO members (Table 13, second column). The fraction of household members with inadequate calorie and protein consumption, however, increased in technology-adopting NGO households, an increase driven primarily by females. The fraction of women consuming inadequate amounts of vitamin A also increased. However, the proportion of male members consuming less than the RDA of protein and iron decreased. Impacts of early access to the technology on nutritional status are mixed (Table 14, second column). Women's hemoglobin levels improved and the fraction of women with low hemoglobin declined significantly as did the fraction of men with low BMI. There were no significant effects on the nutritional status of children.

Finally, early access to technology among program members in Mymensingh resulted in no significant long-term impacts on consumption expenditures, assets, and income levels (Table 12, third column). However, those within the program who received the technology early posted significant gains in iron, protein, and vitamin A consumption by men, and calorie, protein, and vitamin A consumption by women (Table 13, third column). Early access to the technology resulted in some improvements in children's, but not adults', nutritional status. HAZs and ZBMIs for children increased, and the fraction of girls underweight decreased. However, such positive impacts are accompanied by a significant rise in the fraction of children and girls who are stunted. We also observe a decline in BMI among women.

Table 14. Average impact of early access to technology, conditional on program membership, on nutritional status of children and adults, all sites (difference-indifferences estimates)

	Saturia		Jessore		Mymensingh	
Outcome variable: Change between 1996–1997 and 2006–2007 in:	ATT	Obser-vations	ATT	Obser-vations	ATT	Obser-vations
Individual-level outcomes						
HAZ for children	0.58*	31	0.36	17	0.44*	21
	(1.77)		(0.59)		(1.86)	
ZBMI for children	0.99*	31	-0.04	17	1.11**	21
	(1.74)		(-0.08)		(2.43)	
BMI for men	-0.78***	207	0.28	184	0.24	163
	(-2.76)		(0.94)		(0.87)	
BMI for women	0.40	83	-0.34	103	-2.82***	56
	(1.12)		(-0.830)		(-4.05)	
Hemoglobin for women	0.10	61	1.38**	77	0.70	29
	(0.33)		(2.06)		(1.42)	
Household-level outcomes						
Fraction of children with HAZ < -2	-0.075	66	0.107	57	0.285**	72
	(-0.54)		(0.67)		(2.23)	
Fraction of boys with HAZ < -2	0.079	31	-0.175	28	0.000	39
	(0.38)		(-0.70)		(0.00)	
Fraction of girls with HAZ < -2	-1.540***	35	-0.403	28	0.634***	44
	(-9.86)		(-1.59)		(3.26)	
Fraction of children with ZBMI < -2	0.006	66	-0.254	57	0.159	72
	(0.04)		(-1.53)		(1.47)	
Fraction of boys with ZBMI < -2	-0.117	31	0.308	28	-0.064	39
	(-0.48)		(1.19)		(-0.34)	
Fraction of girls with ZBMI < -2	0.282	35	0.077	28	-0.333**	44
	(1.44)		(0.37)		(-2.42)	
Fraction of men with low BMI	-0.026	74	-0.604***	66	0.005	83
	(-0.26)		(-5.62)		(0.06)	
Fraction of women with low BMI	-0.158	86	-0.119	77	-0.161	97
	(-1.23)		(-1.21)		(-1.43)	
Fraction of women with low hemoglobin	0.372**	70	-0.509***	59	0.257	63
	(2.09)		(-2.85)		(1.35)	

Source: Authors' computations from IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Notes: HAZ = height-for-age Z-score; ZBMI = body mass index Z-score; BMI = body mass index; ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively; t-statistics are in parentheses.

6. COMPARING SHORT-TERM AND LONG-TERM IMPACTS: SUMMARY AND CONCLUSION

Table 15 compares single-difference impacts of early adoption in all three sites in 1996–1997 (a measure of short-term impact) and in 2006–2007 (a measure of long-term impact), as well as the double-difference estimates of "sustained impact" on household consumption, assets, and income; nutrient availability and intake; and individual nutritional status.

Across all three sites, the biggest monetary returns to early adoption at the household level are in the individually operated fishponds sites, where there are clear long-term gains in terms of household consumption expenditures. These sustained impacts were achieved despite negative short-term impacts, reflected in lower monthly food and nonfood expenditures and per capita incomes among early adopters of the individually operated fishpond technology in the 1996–1997 round. The pattern of sustained impacts differs sharply from that at the improved vegetables sites, which posted significant gains in per adult equivalent food and nonfood expenditures compared with comparison households early on, but negative (though insignificant) long-term impacts in 2006–2007, and negative double-difference estimates of sustained impact in terms of food and nonfood expenditure, total assets, land owned, and per capita household income. In the improved vegetables sites, early adopters benefitted from lower unit costs and reaped short-term gains referred to as quasi-rents. Because improved vegetable technologies are easy to disseminate, it is no surprise that any initial advantage (or quasi-rents) accruing to the early adopters disappeared once the vegetables were more widely disseminated. In contrast, both the short-term and long-term impacts of early adoption in the group-operated fishponds sites were largely insignificant. Thus, even if the technologies disseminated in Jessore and Mymensingh were very similar, early adopters in Mymensingh were better able to capture the long-term sustained gains. This occurred possibly because over time, *Banchte Shekha* disseminated the group-operated fishpond technologies outside the original treatment area. Moreover, because several families would be sharing the quasi-rents from a single fishpond, benefits to individual families would be diluted. The quasi-rents did not disappear in Mymensingh because the technology was more difficult to adopt and required owning a pond.

Changes in nutrient adequacy follow from changes in per capita or adult-equivalent incomes or expenditures through changes in food expenditures, food consumption, and individual food intake. Thus, given the large gains in per capita expenditures, it is not surprising that early-adopting households in the individually operated fishponds sites posted the most significant sustained reductions in the proportions of household members consuming less than the RDA of calories, protein, and vitamin A, even if short-term impacts on nutrient deficiencies were negative. In the group-operated fishponds sites, although impacts on expenditure outcomes were insignificant, the double-difference estimates indicate that early adopters did less well in terms of the proportion of household members who were able to meet their calorie and protein needs. Interestingly, despite negative differential impacts on monetary measures of consumption expenditures, income, and assets, early adopters of the vegetable technology did not differ significantly from late adopters in terms of nutrient deficiencies.

How food intake is translated into nutritional status at the individual level depends on factors that include caregiving and care-seeking behavior, illness, and work effort. Despite the minimal monetary gains in the improved vegetables sites, early adopters achieved sustained improvements in nutritional status, particularly for women and children. The proportion of stunted girls (HAZ < -2) decreased differentially by 28 percentage points, while the proportion of thin boys decreased differentially by 43 percentage points. Women's BMI also increased differentially among early adopters. However, men's BMIs are lower among early-adopting households. Differential impacts on nutritional status in the group-operated fishponds site indicate some reversals of the short-term impacts. Whereas stunting and thinness rates for boys appear to have been higher among early adopters, these rates declined for boys in early-adopting households over the long term. However, stunting rates for girls are higher among early-adopting families, and there are no significant sustained impacts on adult nutritional status.

Table 15. Summary table of single-difference and double-difference estimates

Outcomes	Saturia			Jessore			Mymensingh		
	Single difference (1996–1997)	Single difference (2006–2007)	Double difference	Single difference (1996–1997)	Single difference (2006–2007)	Double difference	Single difference (1996–1997)	Single difference (2006–2007)	Double difference
Adult-equivalent monthly food expenditure	0.156**	-0.072	-0.228**	0.110	0.061	-0.048	-0.230***	0.026	0.255***
Adult-equivalent monthly household expenditure	0.141*	-0.056	-0.197**	0.127	0.089	-0.039	-0.168**	-0.004	0.163*
Value of total assets	0.164	-0.382*	-0.295**	0.083	0.244	-0.082	-0.305	0.016	0.042
Area of land owned	0.009	-16.115	-0.546**	0.127	1.387	0.161	-0.037	4.610	0.322
Per capita household income	0.126	-0.259	-0.370*	0.207**	0.070	-0.136	-0.205**	-0.202*	-0.009
Per adult equivalent calorie availability	820.93	-290.65	-135.7	482.42	322.33**	-220.5	-1,280.27***	-52.81	954.7
Fraction of household members consuming less than RDA calories	0.004	-0.012	-0.016	-0.062	0.115*	0.176***	0.031	-0.118**	-0.149**
Fraction of household members consuming less than RDA protein	0.010	-0.037	-0.048	-0.063	0.083	0.146*	0.087*	-0.081	-0.168**
Fraction of household members consuming less than RDA iron	0.034	0.003	-0.03	-0.054	-0.043	0.01	-0.071	-0.073*	-0.002
Fraction of household members consuming less than RDA vitamin A	0.026	-0.089*	-0.114	-0.013	0.030	0.043	0.069	-0.125**	-0.194**
Fraction of boys with HAZ < -2	-0.100	0.105	-0.284	0.164*	-0.136	-0.411**	-0.085	-0.217*	-0.146
Fraction of girls with HAZ < -2	0.007	-0.114	-0.284*	0.112	0.252**	0.438**	-0.120	0.438***	0.293*
Fraction of boys with ZBMI < -2	0.106	-0.125	-0.432***	0.185*	0.002	-0.621***	-0.033	-0.091	-0.22
Fraction of girls with ZBMI < -2	0.024	0.066	-0.108	-0.233***	-0.140	-0.069	-0.075	0.104	-0.563***
BMI for men	-0.083	-0.754**	-0.391*	-0.505*	-0.595*	-0.099	-0.389	-0.308	-0.181
Fraction of men with low BMI	-0.085	-0.104	0.086	0.098	0.106	-0.048	0.133	0.002	-0.06
BMI for women	-1.308***	-0.720	0.539*	0.002	-0.626	0.368	-0.978*	-6.101***	-0.504
Fraction of women with low BMI	0.004	0.002	0.004	0.011	-0.048	-0.061	0.121	0.008	-0.085
Hemoglobin for women	-0.471	-0.989***	0.035	-0.586	-0.725**	0.235	0.207	2.374***	0.01
Fraction of women with low hemoglobin	0.045	-0.002	0.002	0.191**	0.188*	-0.082	0.112	0.094	-0.295**

Source: Authors' computations from IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Notes: RDA = recommended daily allowance; HAZ = height-for-age Z-score; ZBMI = body mass index Z-score; BMI = body mass index; ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively.

Given the significant monetary gains and improved nutrient adequacy among early adopters of the individually operated fishponds technology, one would have expected large improvements in nutritional status to occur. It is indeed the case that improvements in hemoglobin levels for women in 2006–2007 are reflected in a sustained impact showing a reduction in the proportion of women with low hemoglobin levels. However, while the proportion of thin girls declined, the proportion of stunted girls increased—indicating that sustained impacts on long-term indicators of nutritional status did not occur, despite sizable monetary gains.

Tracing the impact of agricultural technologies on household incomes and individual well-being is a complicated process that is mediated by several factors: differences in dissemination and targeting mechanisms that may affect what types of households adopt and benefit from the technologies; initial existing differences between control and treatment groups (which can be accounted for using matching methods); the degree to which a technology is divisible and easily disseminated outside the treatment group (easier for improved vegetables, more difficult for fishponds, which require lumpy investments); and finally, intrahousehold allocation processes, which determine how gains from the new technology are allocated among household members. This analysis has given us some insights into how such processes result in long-term impacts that are quite different across interventions, and that differ significantly from short-term estimates of those impacts.

APPENDIX: SUPPLEMENTARY TABLE

Table A.1. Probit estimates of the probability of being an early adopter, all sites

Variables	(1) Saturia	(2) Jessore	(3) Mymensingh
Total land in decimals	0.00141 (0.516)	0.000407 (0.283)	0.00501** (2.223)
Total land in decimals squared	2.02e-06 (0.398)	-8.44e-07 (-0.542)	-6.26e-06* (-1.883)
Age of head, years		0.140 (1.269)	0.0141 (0.166)
Age of head squared, years	0.295 (0.922)		
Whether head is between 20 and 40 years old	0.136 (0.194)		
Whether head is over 55 years old		-0.00141 (-1.226)	-0.000563 (-0.660)
Education level of mother of head	0.0106 (0.245)	-0.0939* (-1.826)	-0.0517 (-1.139)
Education level of father of head	0.118* (1.904)	0.0657 (0.981)	-0.0787 (-1.200)
Number of male members having primary education		-0.144 (-0.764)	-0.315* (-1.956)
Number of female members having primary education		-0.0668 (-0.264)	0.234 (1.124)
Number of male members having secondary education	-0.639** (-2.366)	-0.0959 (-0.271)	0.405* (1.877)
Number of female members having secondary education	-1.023 (-1.470)	-0.823 (-1.076)	-0.231 (-0.752)
Highest level of education among female members		0.0180 (0.257)	0.0639 (1.063)
Highest level of education among male members		0.114** (1.971)	0.0699 (1.463)
Highest level of education in the household	0.0799 (1.577)		
Percent of males 0–4 years old	0.0330 (1.459)	-0.00875 (-0.439)	0.00551 (0.276)
Percent of males 5–14 years old	0.0201 (1.121)	-0.0224 (-1.357)	0.0173 (0.952)
Percent of males 15–19 years old	0.0158 (0.741)	-0.00298 (-0.156)	0.0210 (0.897)
Percent of males 20–34 years old	0.0134 (0.635)	-0.0199 (-0.930)	0.0203 (0.851)
Percent of males 35–54 years old	0.0213 (0.809)	-0.0142 (-0.563)	-0.00149 (-0.0515)
Percent of males 55 years and older	0.0287 (0.741)	-0.00787 (-0.269)	0.000629 (0.0189)

Table A.1. Continued

Variables	(1) Saturia	(2) Jessore	(3) Mymensingh
Percent of females 0–4 years old	0.0254 (1.198)	-0.0373 (-1.591)	0.0115 (0.566)
Percent of females 5–14 years old	0.0210 (1.079)	-0.00322 (-0.195)	0.00175 (0.0930)
Percent of females 15–19 years old	0.00578 (0.291)	-0.0239 (-1.178)	-0.0265 (-1.192)
Percent of females 20–34 years old	-0.00509 (-0.268)	0.00927 (0.474)	-0.0200 (-1.245)
Percent of females 35–54 years old	0.0105 (0.594)	0.0153 (0.804)	
Percent of females 55 years and older			0.0237 (1.350)
Whether the village is electrified		0.0161 (0.0422)	0.253 (0.592)
Whether the access road is Katcha		0.379 (0.877)	0.0846 (0.309)
Proportion of households affected by flood, 2002–2007	0.0216** (2.325)		
Whether household experienced flood shock, 1996–2006	-0.490** (-2.082)	-0.912 (-1.390)	-0.316 (-0.902)
Whether household experienced livestock shock, 1996–2006	0.285 (1.233)	-0.275 (-1.065)	-0.0964 (-0.335)
Whether household experienced illness shock, 1996–2006	-0.109 (-0.508)	-0.181 (-0.856)	-0.189 (-0.849)
Whether household experienced crop loss, 1996–2006	-0.145 (-0.402)		
Whether household experienced legal/political shock, 1996–2006	-0.0371 (-0.150)		
Whether the household paid dowry or other wedding expenses, 1996–2006	-0.0478 (-0.167)	-0.331 (-1.378)	0.146 (0.568)
Constant	-1.788 (-1.018)	-2.563 (-0.850)	-1.436 (-0.521)
Observations	219	225	224

Source: Authors' computations from IFPRI Chronic Poverty and Long-term Impact Study in Bangladesh Dataset.
Notes: ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively; t-statistics are in parentheses.

REFERENCES

Abadie, A., and G. W. Imbens. 2002. *Simple and bias-corrected matching estimators for average treatment effects*. NBER Technical Working Papers 0283. Cambridge, Mass., U.S.A.: National Bureau of Economic Research, Inc.

Abadie, A., D. Drukker, J. L. Herr, and G. W. Imbens. 2004. Implementing matching estimators for average treatment effects in Stata. *Stata Journal* 4 (3): 290–311.

Alderman, H, J. R. Behrman, H., Kohler, J. A. Maluccio, and S. C. Watkins, 2001. Attrition in longitudinal household survey data. *Demographic Research* (Germany) 5 (4): 79-124.

Baulch, B., and P. Davis. 2008. Poverty dynamics and livelihood trajectories in rural Bangladesh. *International Journal of Multiple Research Approaches* 2 (2): 176-190.

BBS (Bangladesh Bureau of Statistics). 2006. Preliminary report on household income and expenditure survey, 2005. Planning Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

Bouis, H., B. de la Brière, L. Guitierrez, K. Hallman, N. Hassan, O. Hels, W. Quabili, A. Quisumbing, S. Thilsted, Z. Hassan Zihad, and S. Zohir. 1998. *Commercial vegetable and polyculture fish production in Bangladesh: Their impacts on income, household resource allocation, and nutrition.* Washington, D.C., and Dhaka: International Food Policy Research Institute and Bangladesh Institute of Development Studies, Institute of Nutrition and Food Science.

Davis, P. 2007. *Discussion among the poor: Exploring poverty dynamics with focus groups in Bangladesh.* CPRC Working Paper 84. Manchester, U.K.: Chronic Poverty Research Centre.

Gilligan, D., and J. Hoddinott. 2007. Is there persistence in the impact of emergency food aid? Evidence on consumption, food security, and assets in rural Ethiopia. *American Journal of Agricultural Economics* 89 (2): 1–18.

Gilligan, D., J. Hoddinott, and A. S. Taffesse. 2009. An analysis of Ethiopia's Productive Safety Net Programme and its linkages. *Journal of Development Studies* 45 (10): 1684–1706.

Hallman, K., D. Lewis, and S. Begum. 2007. Assessing the impact of vegetable and fishpond technologies on poverty in rural Bangladesh. In *Agricultural research, livelihoods, and poverty: Studies of economic and social impacts in six countries*, ed. M. Adato and R. Meinzen-Dick. Baltimore: Johns Hopkins University Press.

Heckman, J., H. Ichimura, and P. E. Todd. 1997. Matching as an econometric evaluation estimator: Evidence from evaluating a job training programme. *Review of Economic Studies* 64 (4): 605–654.

________. 1998. Matching as an econometric evaluation estimator. *Review of Economic Studies* 65 (2): 261–294.

Hoddinott, J., J. Maluccio, J. Behrman, R. Flores, and R. Martorell. 2008. The impact of nutrition during early childhood on income, hours worked, and wages of Guatemalan adults. *Lancet* 371: 411–416.

King, E. M., and J. R. Behrman. 2008. *Timing and duration of exposure in evaluation of social programs*. Policy Research Working Paper Series 4868. Washington, D.C.: World Bank.

Maluccio, J., J. Hoddinott, J. Behrman, R. Martorell, A. Quisumbing, and A. D. Stein. 2009. The impact of improving nutrition during early childhood on education among Guatemalan adults. *Economic Journal* 119 (April): 734–763.

Naved, R. T. 2000. *Intrahousehold impact of transfer of modern agricultural technology: A gender perspective*. Food Consumption and Nutrition Division Discussion Paper 85. Washington, D.C.: International Food Policy Research Institute.

NIPORT (National Institute of Population Research and Training)/Mitra and Associates/Macro International. 2009. *Bangladesh demographic and health survey 2007.* Dhaka and Calverton, Maryland, U.S.A.

Orbicon and Lamans Management Services. 2009. *Impact evaluation of aquaculture interventions in Bangladesh*. Copenhagen: Ministry of Foreign Affairs, Denmark.

Quisumbing, A. 2007. *Poverty transitions, shocks, and consumption in rural Bangladesh: Preliminary results from a longitudinal household survey*. CPRC Working Paper 105. Manchester, U.K.: Chronic Poverty Research Center.

Quisumbing, A., and B. de la Brière. 2000. *Women's assets and intrahousehold allocation in rural Bangladesh: Testing measures of bargaining power.* Food Consumption and Nutrition Division Discussion Paper 86. Washington, D.C.: International Food Policy Research Institute.

Quisumbing, A., and J. Maluccio. 2003. Resources at marriage and intrahousehold allocation: Evidence from Bangladesh, Ethiopia, Indonesia, and South Africa. *Oxford Bulletin of Economics and Statistics* 65 (3): 283–328.

Sen, B., and D. Hulme. 2006. *Chronic poverty in Bangladesh: Tales of ascent, descent, marginality, and persistence*. Dhaka: Bangladesh Institute of Development Studies.

Smith, L. C., U. Ramakrishnan, A. Ndiaye, L. Haddad, and R. Martorell. 2003. *The importance of women's status for child nutrition in developing countries.* Washington, D.C.: International Food Policy Research Institute.

Sunding, D., and D. Zilberman. 2001. The agricultural innovation process: Research and technology adoption in a changing agricultural sector. In *Handbook of agricultural economics*, vol. 1A, ed. B. L. Gardner and G. C. Rausser. Amsterdam: North Holland.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to http://www.ifpri.org/publications/results/taxonomy%3A468.
All discussion papers can be downloaded free of charge.

994. Economics of export taxation in a context of food crisis: A theoretical and CGE approach contribution. Antoine Bouët and David Laborde Debucquet, 2010.

993. What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach. Liangzhi You, Claudia Ringler, Gerald Nelson, Ulrike Wood-Sichra, Richard Robertson, Stanley Wood, Zhe Guo, Tingju Zhu, and Yan Sun, 2010.

992. *Impact of farmer field schools on agricultural productivity and poverty in East Africa*. Kristin Davis, Ephraim Nkonya, Edward Kato, Daniel Ayalew Mekonnen, Martins Odendo, Richard Miiro, and Jackson Nkuba, 2010.

991. *Exploring the long-term impact of development interventions within life-history narratives in rural Bangladesh*. Peter Davis, 2010.

990. *The costs and benefits of duty-free, quota-free market access for poor countries: Who and what matters?* Antoine Bouët, David Laborde Debucquet, Elisa Dienesch, and Kimberly Elliot, 2010.

989. *Mountains, global food prices, and food security in the developing world*. Kamiljon T. Akramov, Bingxin Yu, and Shenggen Fan, 2010.

988. *Examining the dynamic relationship between spot and future prices of agricultural commodities*. Manuel Hernandez and Maximo Torero, 2010.

987. *Dynamic agricultural supply response under economic transformation: A case study of Henan Province.* Bingxin Yu, Fengwei Liu, and Liangzhi You, 2010.

986. *R&D investment in national and international agricultural research: An ex-ante analysis of productivity and poverty impact.* Alejandro Nin Pratt and Shenggen Fan, 2010

985. *Food security and economic development in the Middle East and North Africa: Current state and future perspectives.* Clemens Breisinger, Teunis van Rheenen, Claudia Ringler, Alejandro Nin Pratt, Nicolas Minot, Catherine Aragon, Bingxin Yu, Olivier Ecker, and Tingju Zhu, 2010.

984. *Improving resource allocation and incomes in Vietnamese agriculture: A case study of farming in the Dong Nai River Basin*. Joshua Dewbre, 2010.

983. *Positional spending and status seeking in rural China*. Philip H. Brown, Erwin Bulte, and Xiaobo Zhang, 2010.

982. *Assessing food security in Yemen: An innovative integrated, cross-sector, and multilevel approach*. Olivier Ecker, Clemens Breisinger, Christen McCool, Xinshen Diao, Jose Funes, Liangzhi You, and Bingxin Yu, 2010.

981. *Long-term impact of investments in early schooling: Empirical evidence from rural Ethiopia.* Subha Mani, John Hoddinott, and John Strauss, 2010.

980. *Infrastructure and cluster development: A case study of handloom weavers in Ethiopia*. Gezahegn Ayele, Lisa Moorman, Kassu Wamisho, and Xiaobo Zhang, 2010.

979. *Country-level impact of global recession and China's stimulus package: A general equilibrium assessment*. Xinshen Diao, Yumei Zhang, and Kevin Z. Chen, 2010.

978. *Emergence of Sri Lanka in European fish trade: Is there cause for concern in the Lake Victoria Region (East Africa)?* Andrew Muhammad and Guyslain Ngeleza, 2010.

977. *China has reached the Lewis Turning Point*. Xiaobo Zhang, Jin Yang, and Shenglin Wang, 2010.

976. *The medium-term impact of the primary education stipend in rural Bangladesh*. Bob Baulch, 2010.

975. *A review of empirical evidence on gender differences in nonland agricultural inputs, technology, and services in developing countries.* Amber Peterman, Julia Behrman, and Agnes Quisumbing, 2010.

974. *An experiment on the impact of weather shocks and insurance on risky investment.* Ruth Vargas Hill and Angelino Viceisza, 2010.

973. *Engendering agricultural research.* Ruth Meinzen-Dick, Agnes Quisumbing, Julia Behrman, Patricia Biermayr-Jenzano, Vicki Wilde, Marco Noordeloos, Catherine Ragasa, Nienke Beintema, 2010.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org

IFPRI ADDIS ABABA

P. O. Box 5689
Addis Ababa, Ethiopia
Tel.: +251 11 6463215
Fax: +251 11 6462927
Email: ifpri-addisababa@cgiar.org

IFPRI NEW DELHI

CG Block, NASC Complex, PUSA
New Delhi 110-012 India
Tel.: 91 11 2584-6565
Fax: 91 11 2584-8008 / 2584-6572
Email: ifpri-newdelhi@cgiar.org